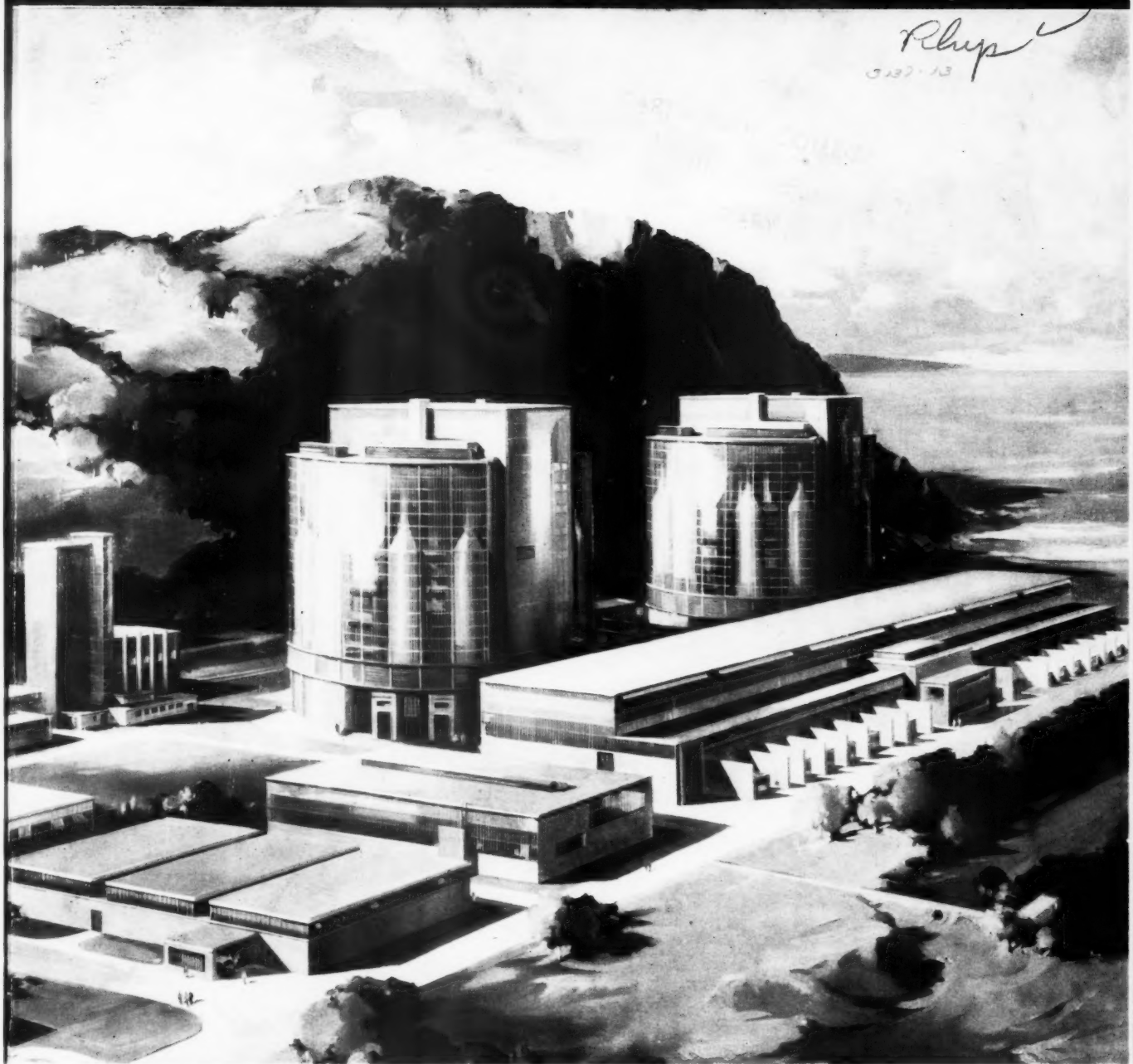
ELCROSS — full colour drawing and description

Nuclear Power

THE JOURNAL OF BRITISH NUCLEAR ENGINEERING



A238

An artist's impression of the new 360,000 kw Nuclear Power Station under construction at Hunterston

G.E.C.

ATOMIC ENERGY DIVISION

THE GENERAL ELECTRIC CO. LTD. MAGNET HOUSE · KINGSWAY · W.C.2.

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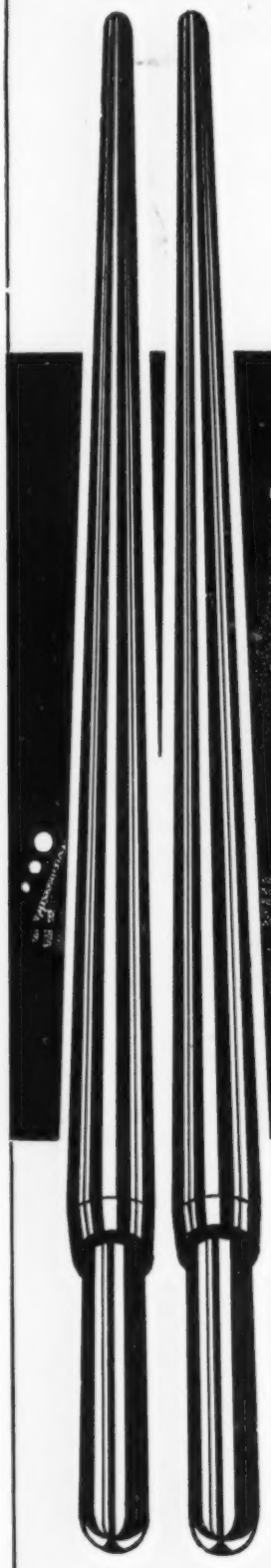

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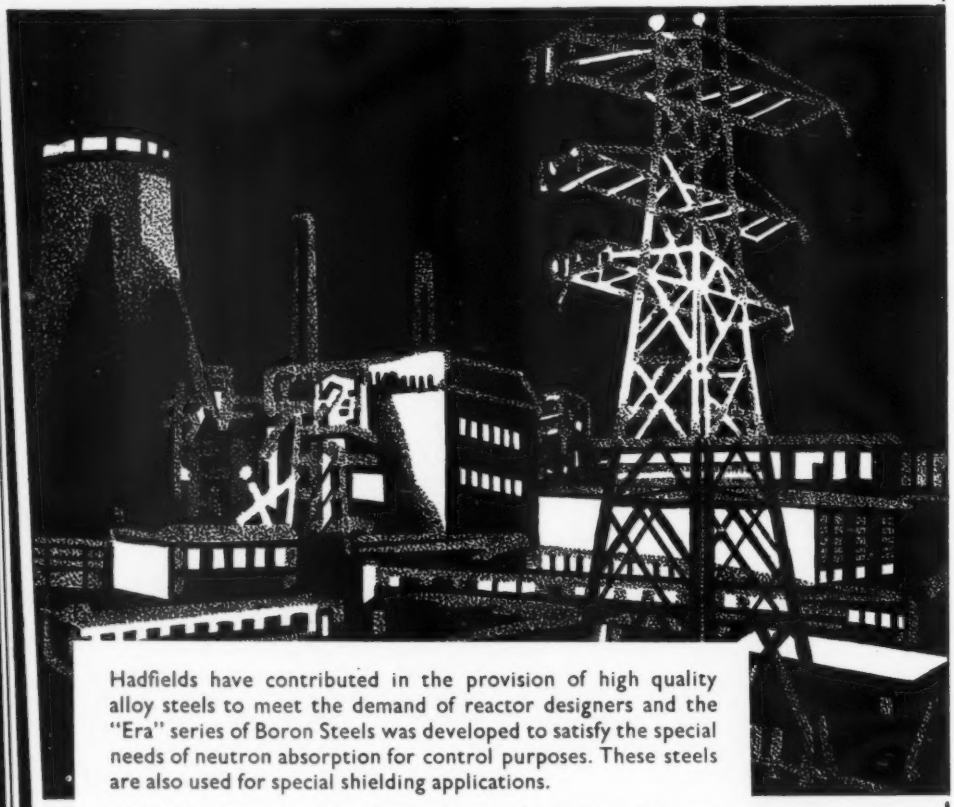

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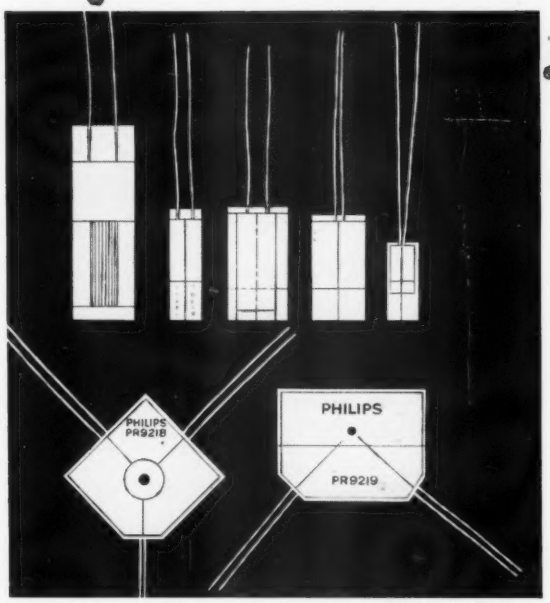

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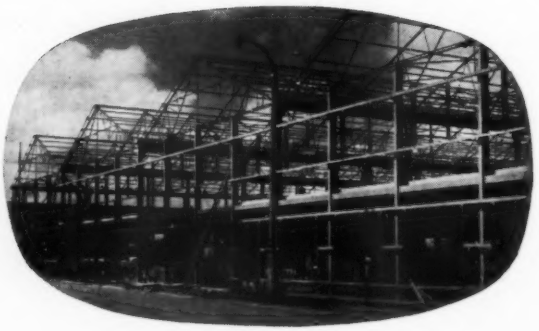

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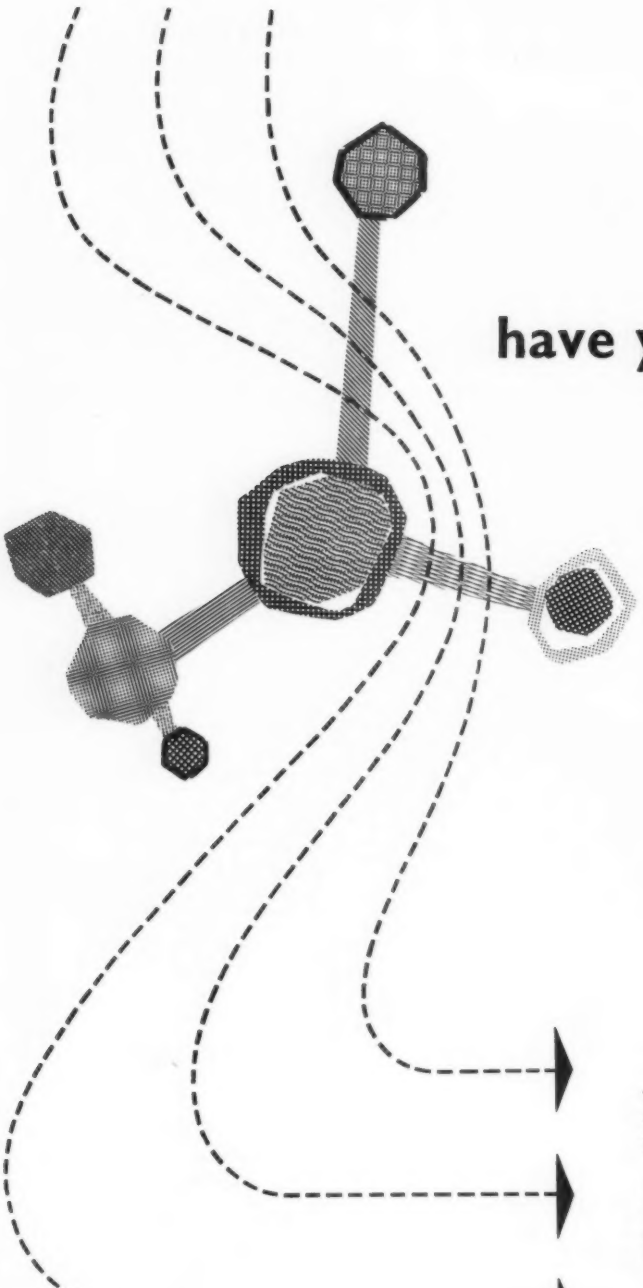

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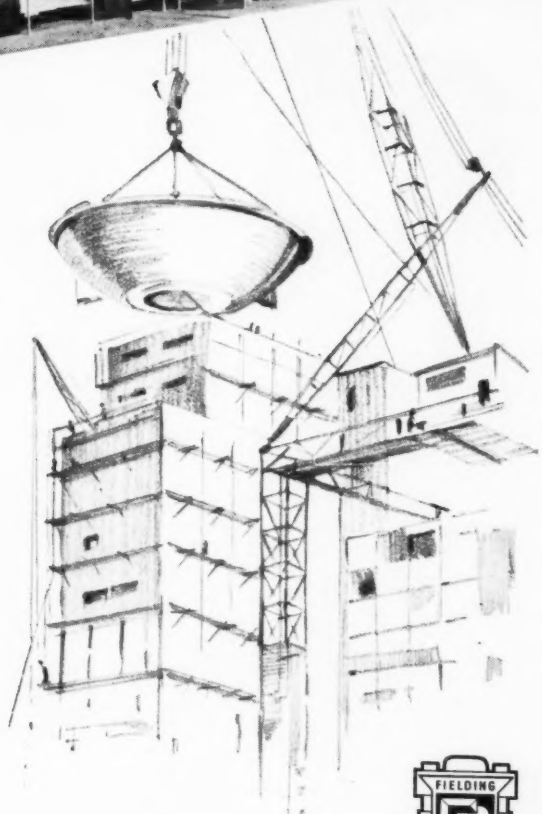

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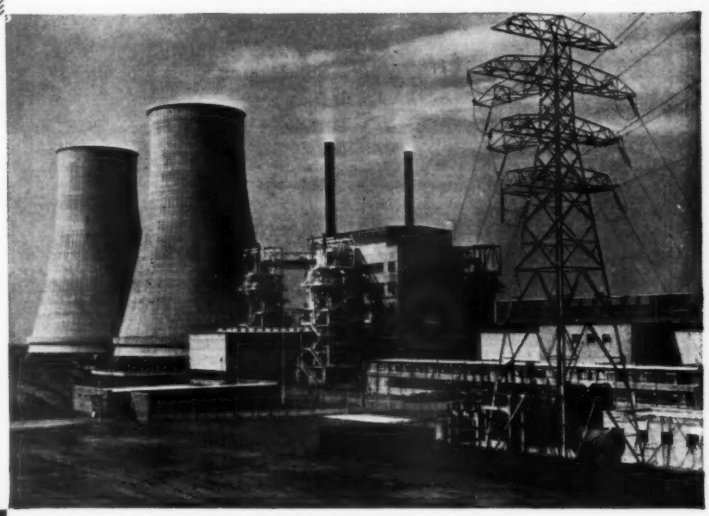

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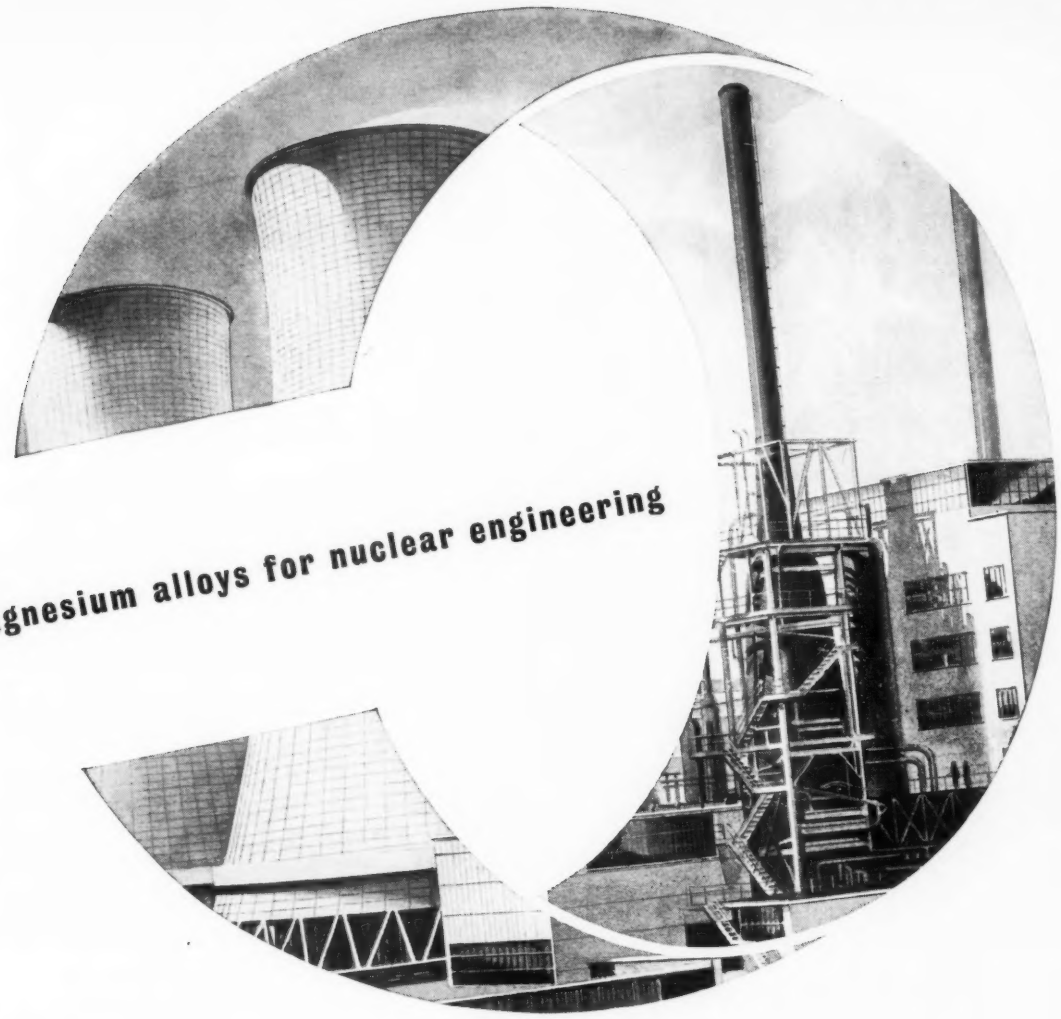

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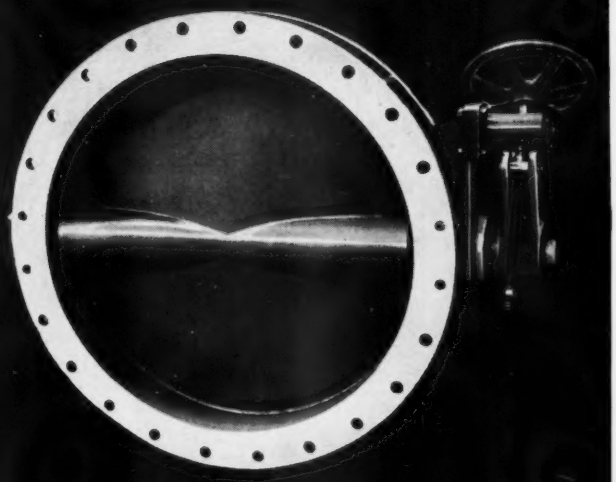
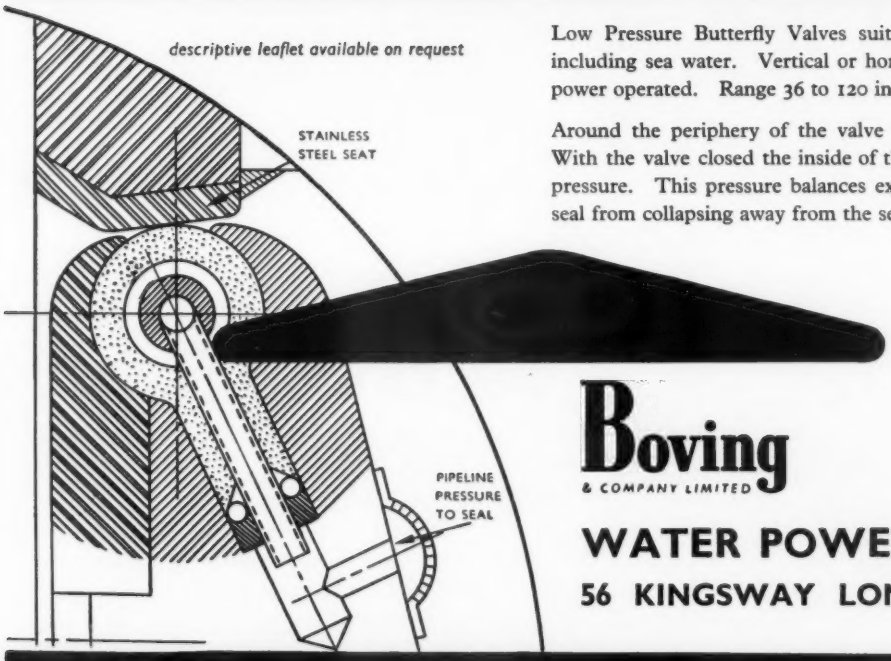


descriptive leaflet available on request



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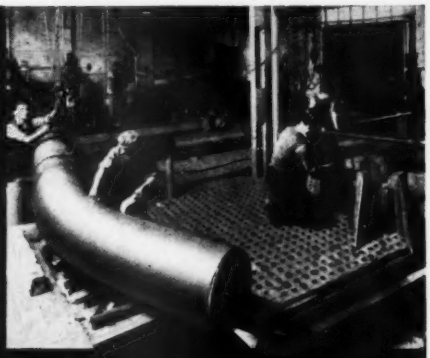
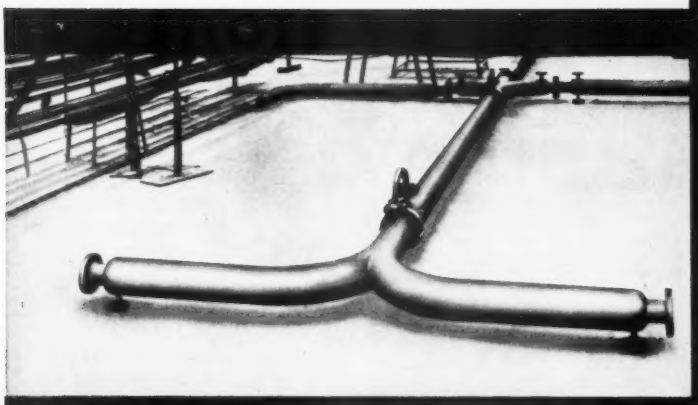


Fire bending process on a large bore steel pipe.



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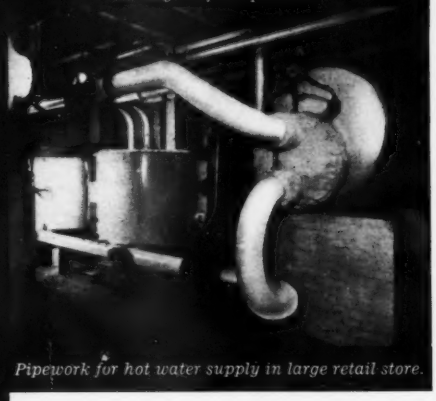

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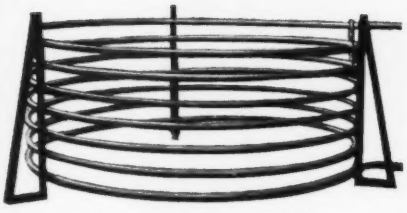

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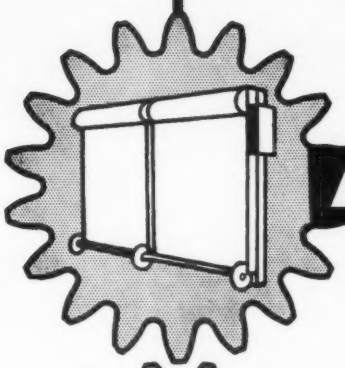

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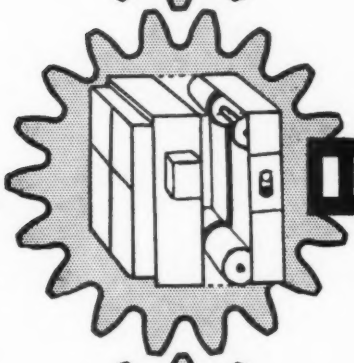

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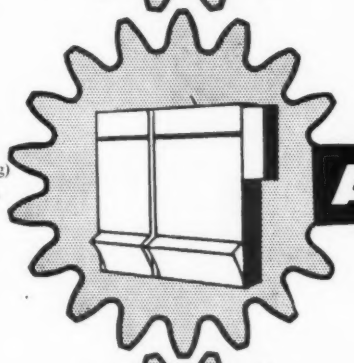

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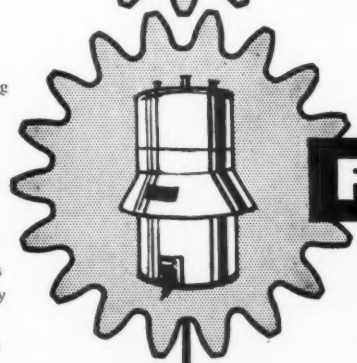

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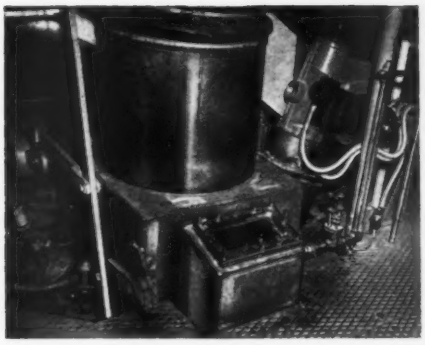

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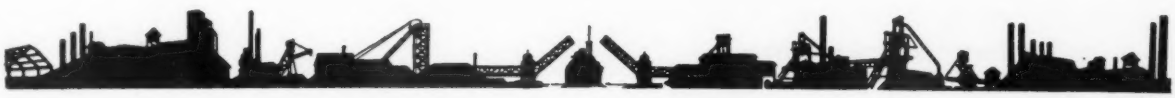

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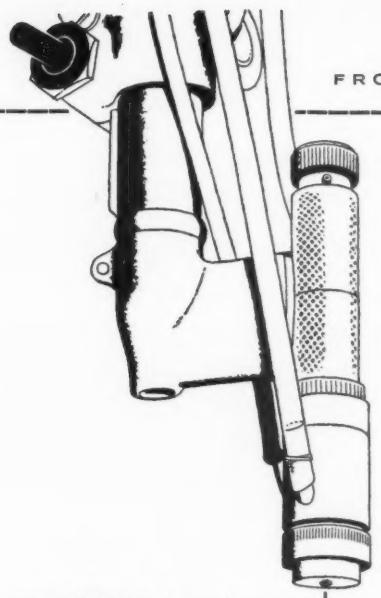

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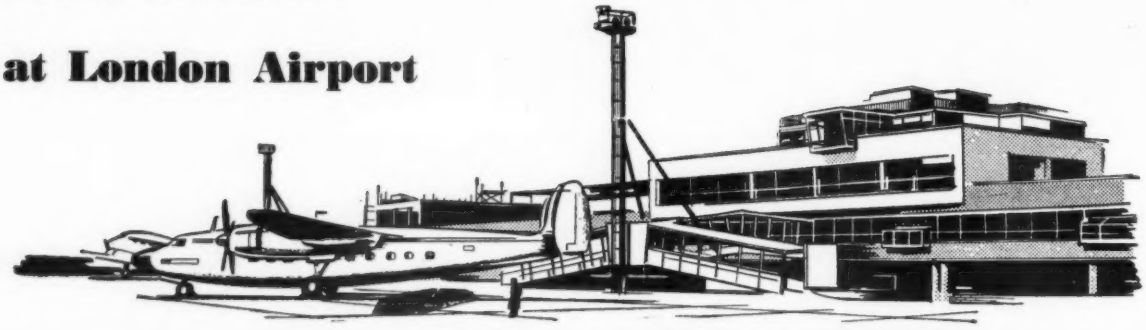

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ARMOURED CABLE

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Illustration shows "CORRUSTEEL" Armoured Cable in the Main Feeder Trunking at London Airport's new building. Electrical Contractors, The L.E.B. Contracting Section, Chelsea Manor Street, S.W.3

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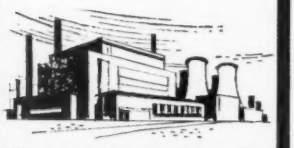
Newalls have carried out the thermal insulation contracts on many of the British Power Stations built since the war.



CHAPELCROSS ▸

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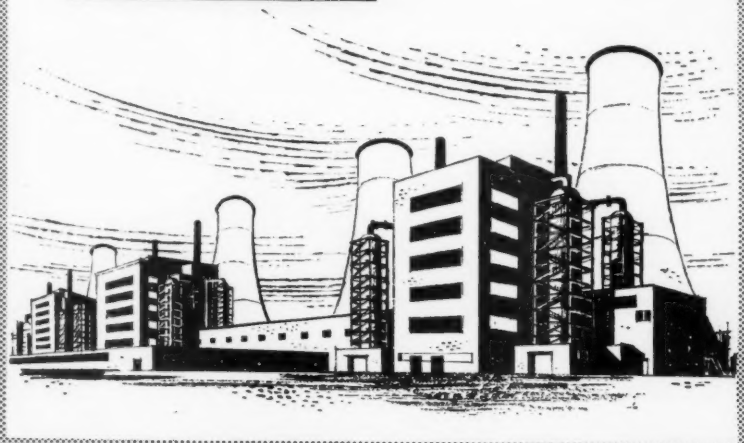

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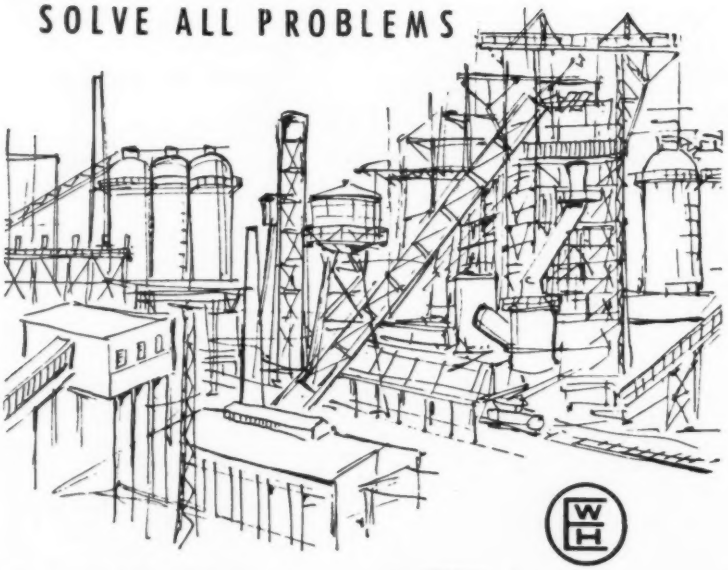

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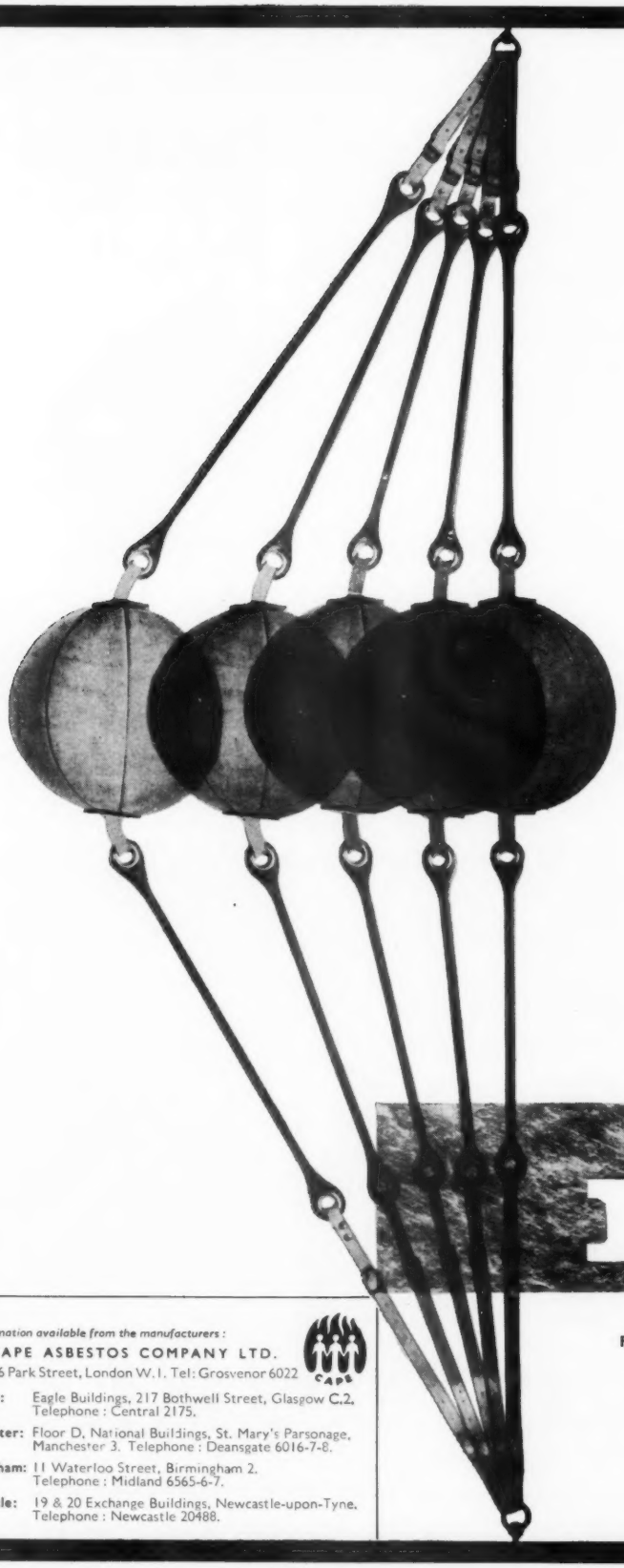

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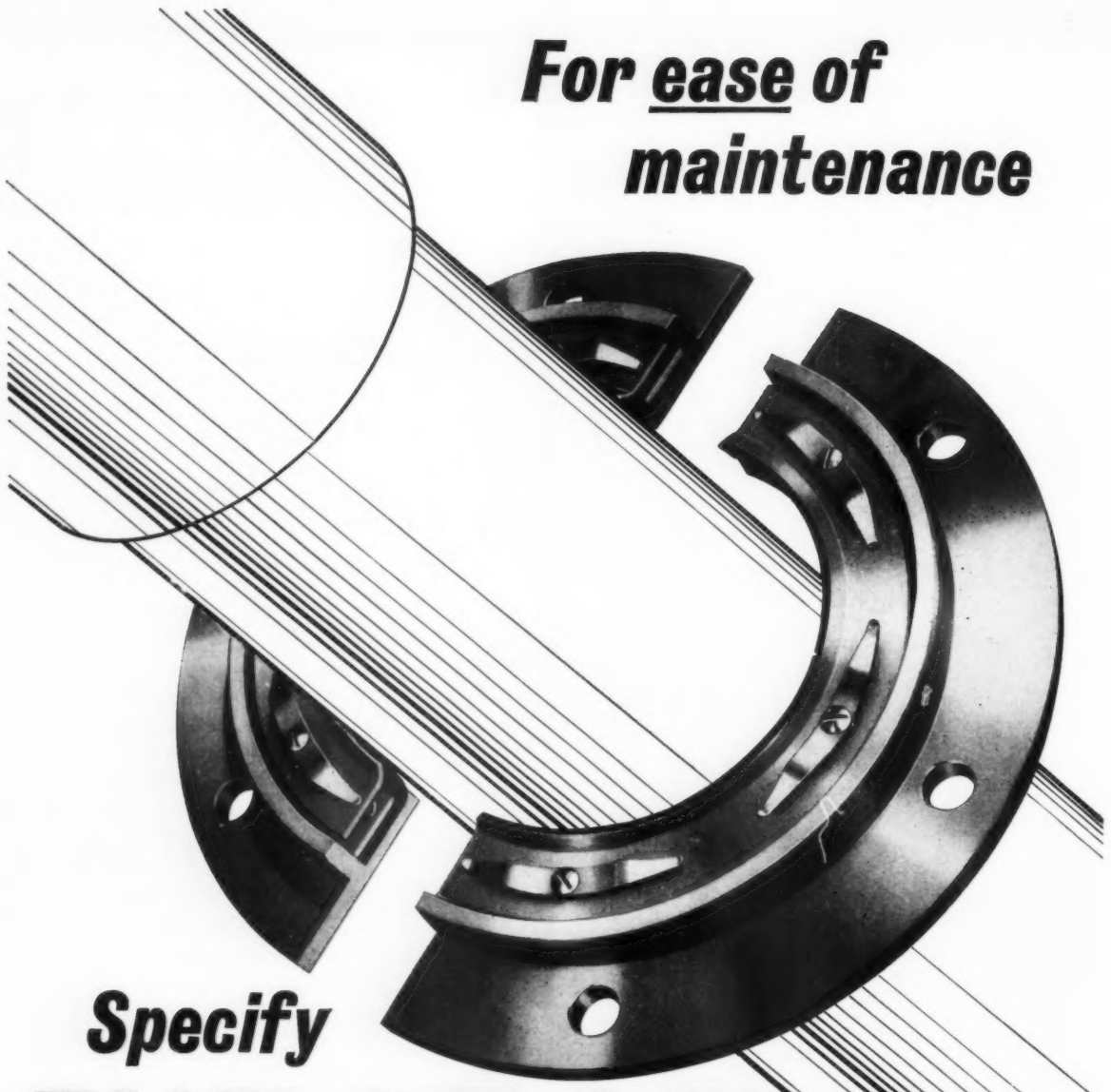

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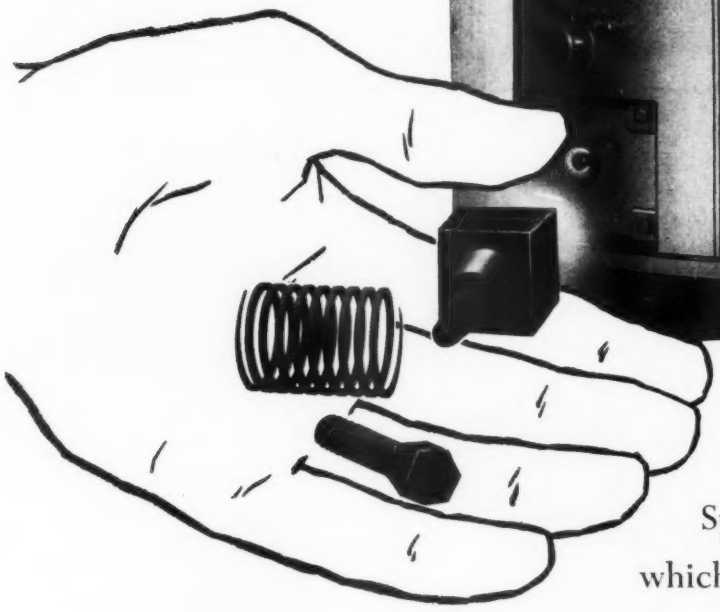

or
like this fragile Graphite Spring and other components which weigh only a few grammes.

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"But why can't they use my magnet?"

"Well, you see Johnny, it's because *your* sort of magnet can't be switched 'on and off'!"

"*Huh! I wouldn't like mine to do that!*"

"I know, but then you don't use yours to control water or gas and things."

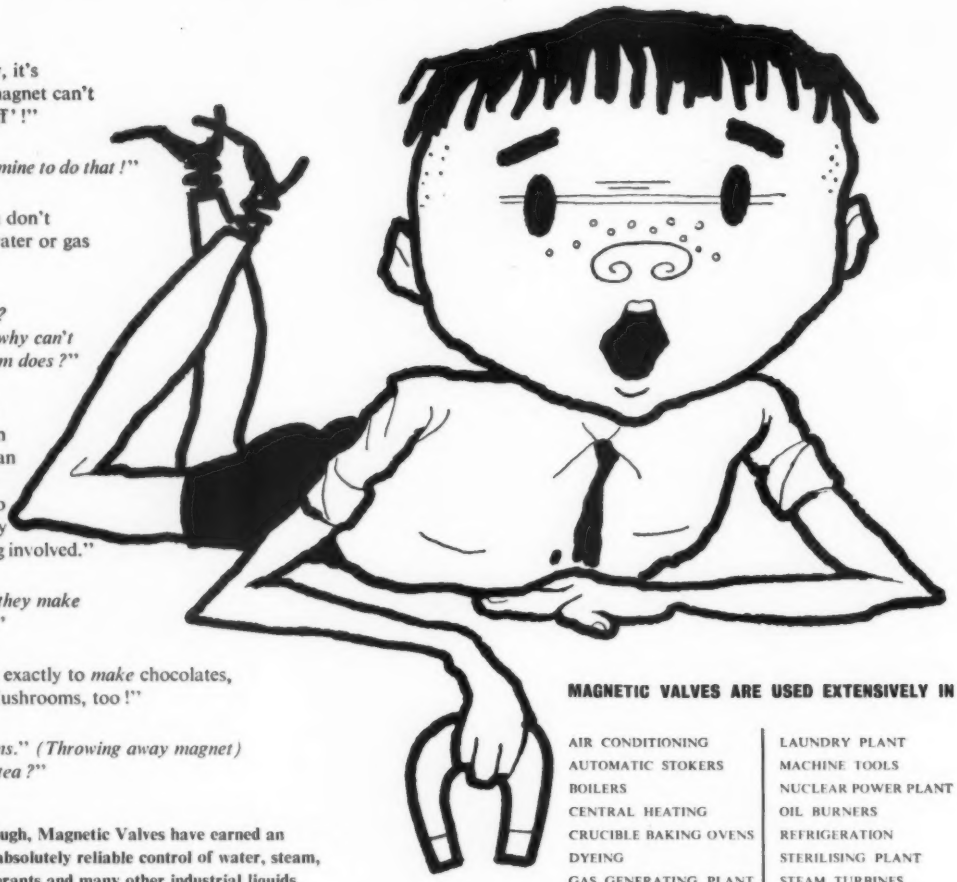
"*Control water or gas? Seems stupid to me — why can't they use a tap like Mum does?*"

"Ah! But using a tap means that you rely on what's called the 'human element'. That's why these valves are fitted to do things automatically —without people being involved."

"*Mr. Stevens told me they make chocolates with them!*"

"That's right, but not exactly to *make* chocolates, to *help* make them. Mushrooms, too!"

"*Cor! I like mushrooms.*" *(Throwing away magnet)*
"*Can I have some for tea?*"



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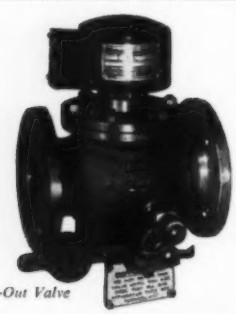

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Magnetic 'PR' Type High Pressure Stop Valve

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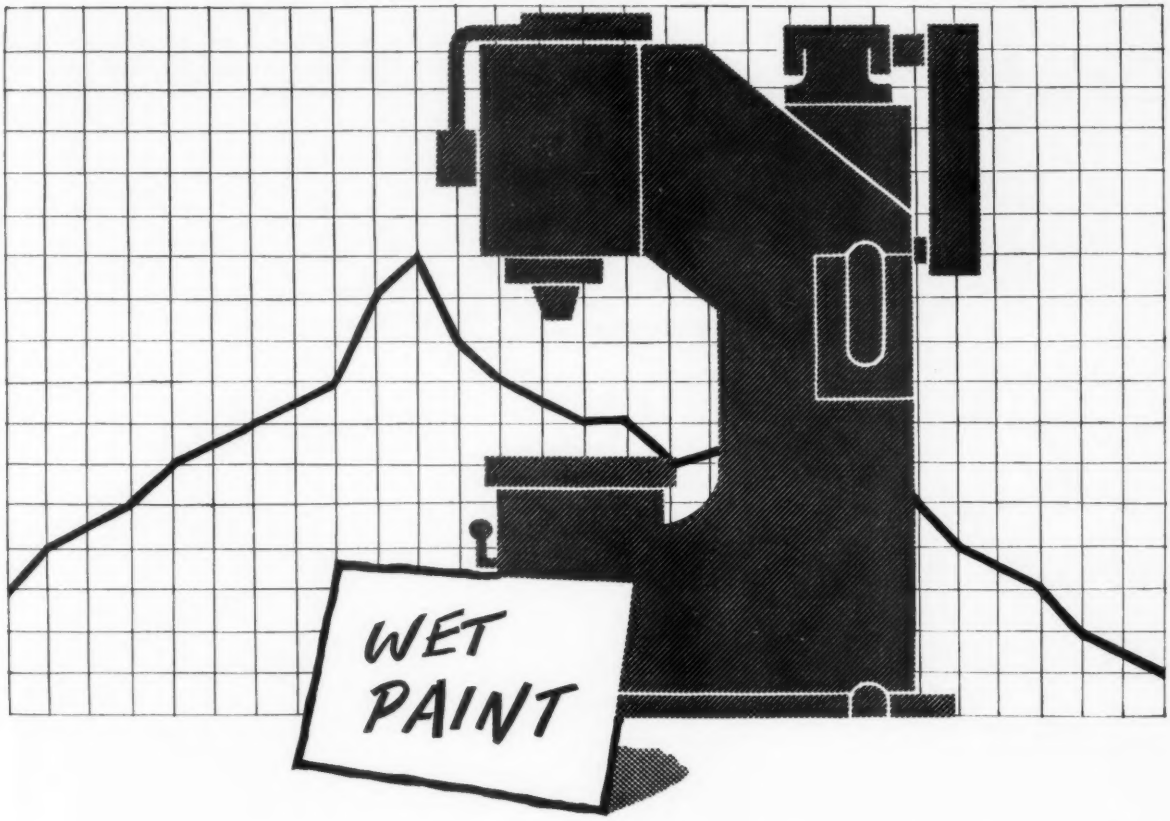

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BPL Machine Enamels, correctly chosen from the comprehensive range according to the conditions obtaining, save hours of time and make a positive contribution towards a non-stop assembly line, increased output and consequently an uplift in morale.
Where special resistances are needed (to the action of chemicals or heat for example) or a new type of machine is to be coated, or even if it's just a case of repainting existing machinery, specialist advice is most desirable; call in our Technical Advisory Service—it is free and without obligation.

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Normal Gloss	B.P.L. Zinc Chromate Metal Primer	'Universal' Undercoat	'Ferreko' Machinery Enamel
Resistant to Heat (up to 350°F.)	B P.L. Heat Resisting Primer M.P.34	B.P.L. Heat Resisting Undercoat	B.P.L. Heat Resisting Enamel
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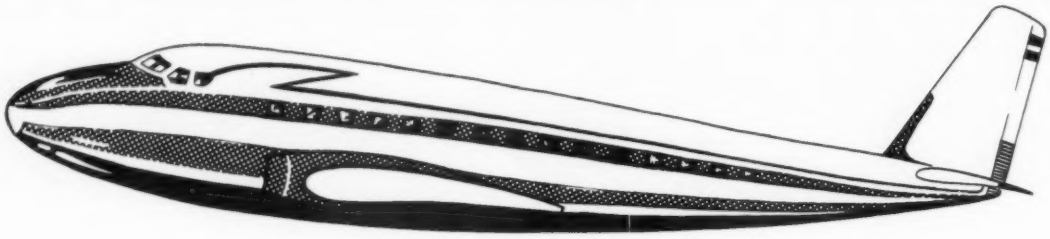
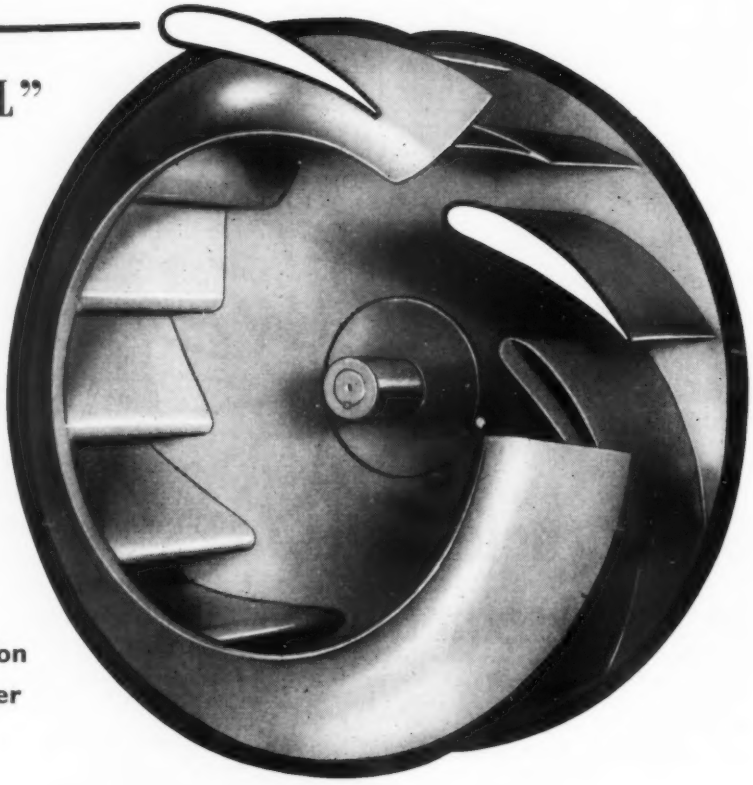


"GYRA-FLO AIRFOIL" IMPELLER BLADES, BLADE SHROUDS and INLET CONES



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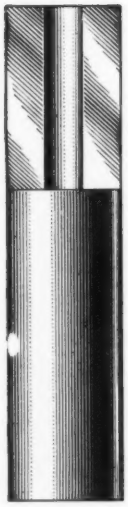
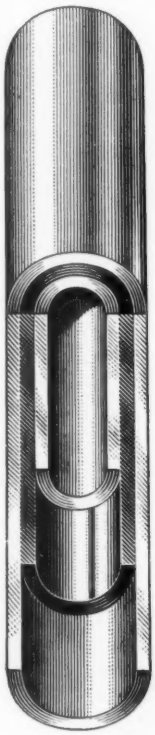
No. 3 OF A SERIES BY ACCLES & POLLOCK



This type of tube, made by a special process which ensures accurate bore dimensions with improved surface finish, is used in plant involving very high pressure work.

Triple composite tube: the mild steel tube is sheathed and lined with copper.



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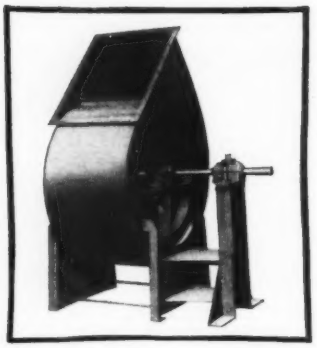
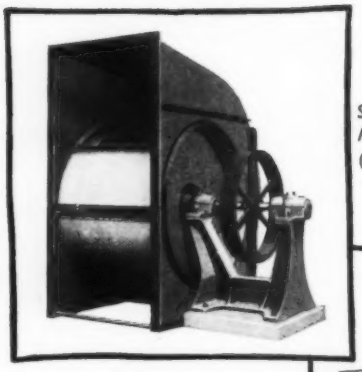
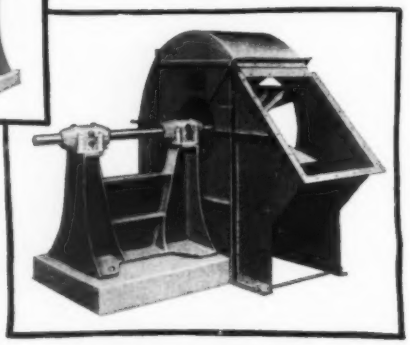


SLOW SPEED MULTIVANE FAN (Intermediate size).



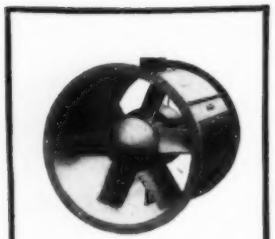
SLOW SPEED MULTIVANE FAN (Large size).

Air ways



PADDLE BLADE FAN.

are our ways



AXIAL FLOW FAN.

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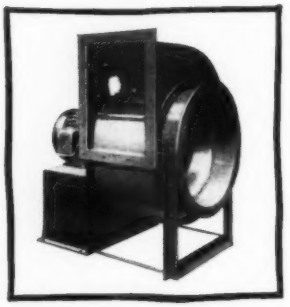
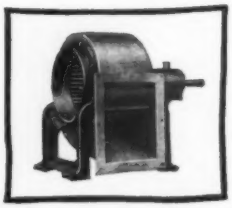


P.V.C. FAN.



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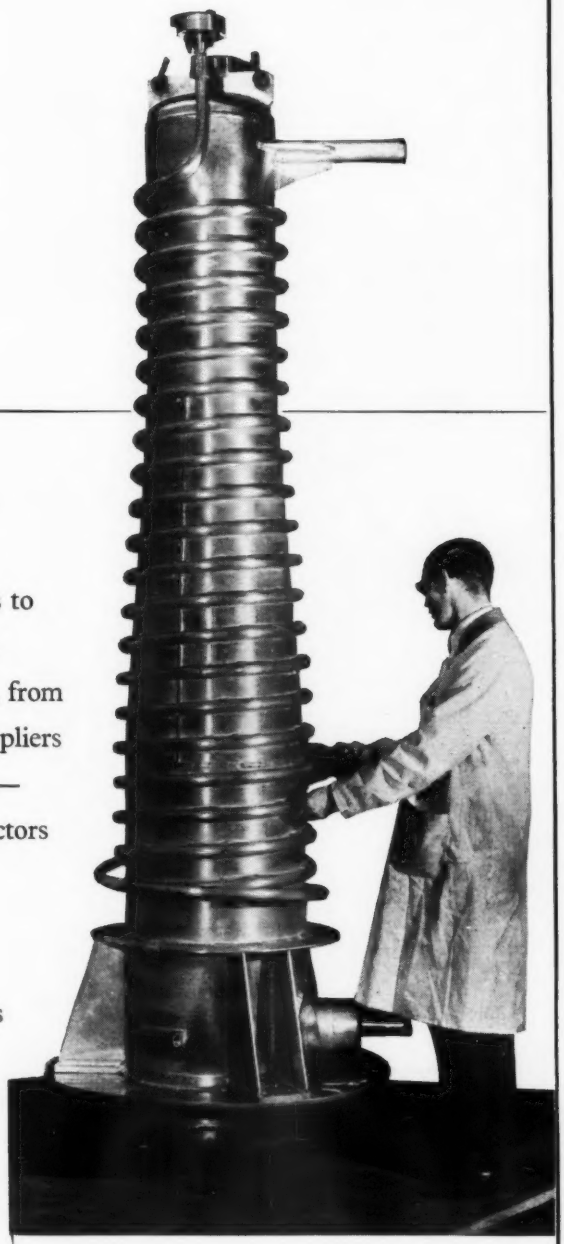

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Nuclear Power
THE JOURNAL OF BRITISH NUCLEAR ENGINEERING

July 1958

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15	40	65	90	115	140	165	190
16	41	66	91	116	141	166	191
17	42	67	92	117	142	167	192
18	43	68	93	118	143	168	193
19	44	69	94	119	144	169	194
20	45	70	95	120	145	170	195
21	46	71	96	121	146	171	196
22	47	72	97	122	147	172	197
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Designed Lighting

Chapel Cross

Special lighting has been designed for the turbine control room by AEI Lamp and Lighting Company in conjunction with the Architects, L. J. Couves and Partners, and Consulting Engineers, Merz and McLellan.

The lighting in the four reactor control rooms follows the successful AEI luminous ceiling design in use at Calder Hall.

A.E.I. Designed Lighting also for

Calder Hall
Capenhurst
Dounreay
Berkeley

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M4774

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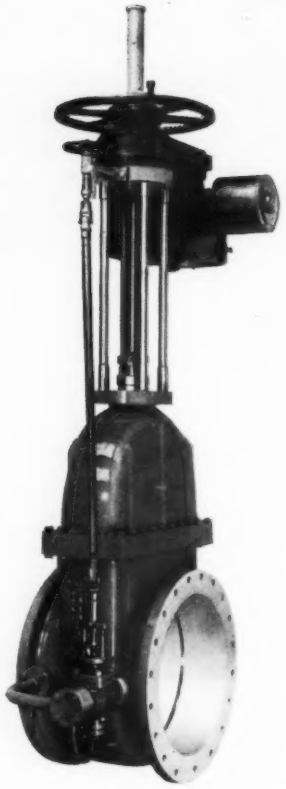
HOPKINSONS' equipment at CHAPEL CROSS

Another nuclear power station* has been supplied with Hopkinsons' valves and allied specialities, including stop valves varying in size from ¾ in. to 28 in. For Chapel Cross we have supplied—electrically-operated parallel-slide valves desuperheating equipment, relief valves, combined stop and isolating valves, automatic exhaust valves, non-return valves. "Uniflow" valves, "Nolos" steam traps, centrifugal oil separators.



26 in. bore Parallel-slide Valve with electric control unit.

20 in. bore Deadweight Relief Valve.

*Hopkinsons' valves and fittings have been supplied or are on order for:

CALDER HALL
DOUNREAY
BERKELEY
HUNTERSTON
CHAPEL CROSS
BRADWELL
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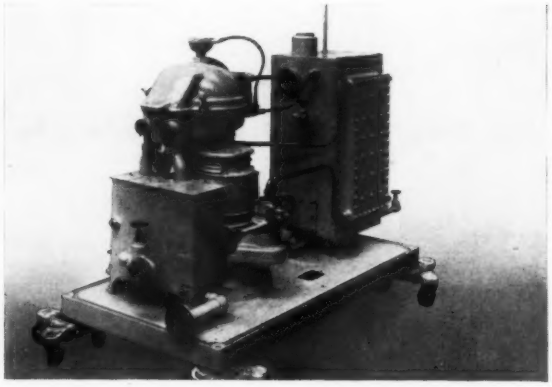

Centrifugal Purifier for continuous purification of turbine lubricating oil.

HOPKINSONS LIMITED · HUDDERSFIELD

LONDON OFFICE: 34 NORFOLK STREET · STRAND · W.C.2

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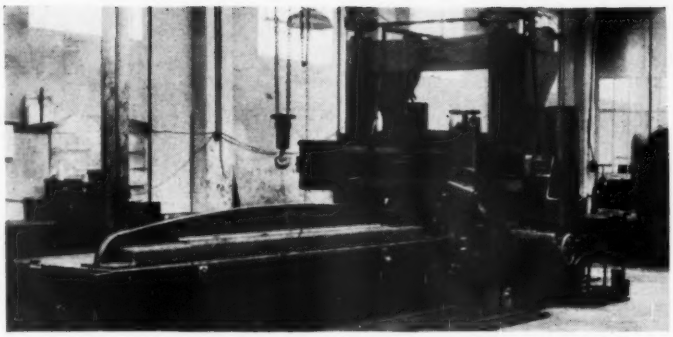

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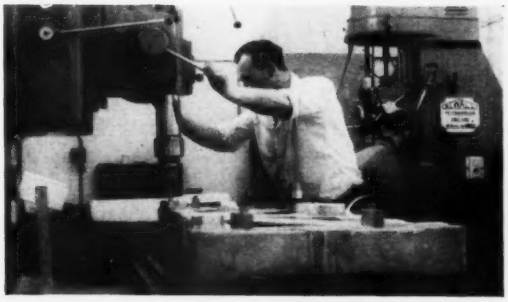
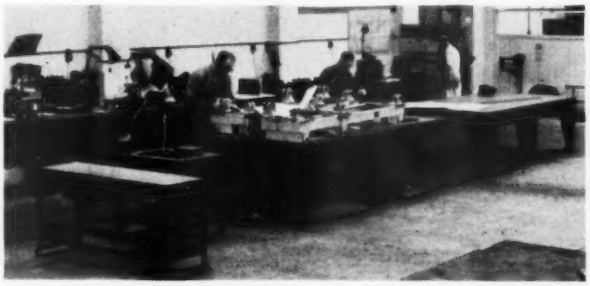


Two of three jig borers. Capacity 28 ins. × 28 ins.



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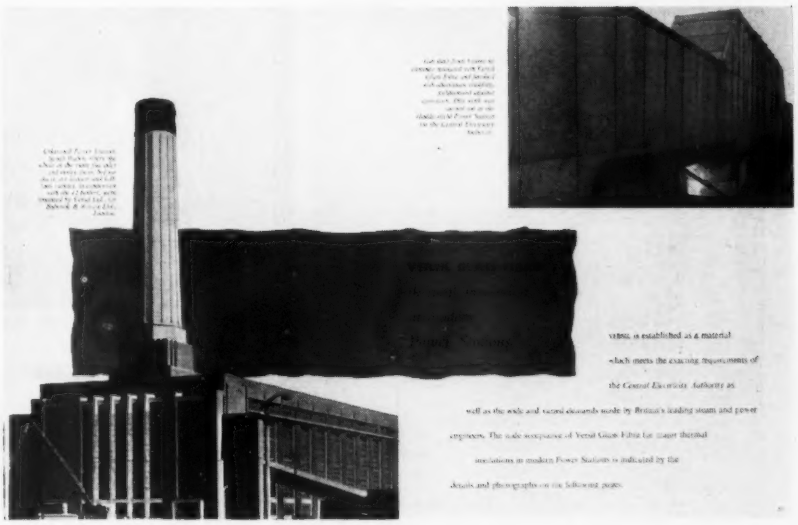
And so another contract is won by VERSIL, to add to an already impressive list of industrial insulations carried out by the Versil Contracts Department, one of the most important of which is the extensive insulation work† at Chapelcross, which was awarded to Versil by Messrs Merz and McLellan.

† *High and low pressure steam mains and auxiliary steam piping and feed, drain and damp steam piping within and external to the turbine hall, together with the surge tanks.*



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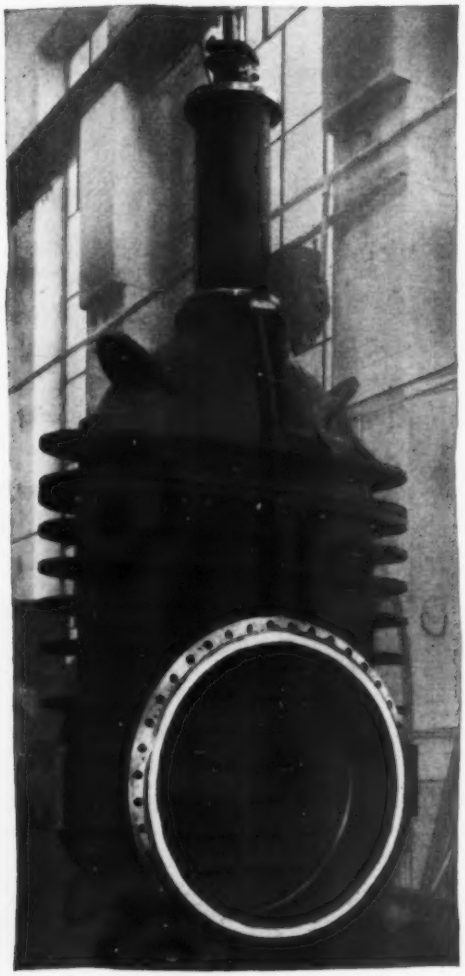
Blakeborough valves for Chapel Cross

Blakeborough valves were chosen for the main gas circuits on all reactors at the Chapel Cross nuclear power station. These valves (thirty two in all) are of wedge gate type, 54 in. diameter, in cast steel, with electric motor driven operating gear—a repeat of those already supplied for Calder Hall.



54" Cast Steel Gate Valve in course of assembly.

Including the 60 in. diameter stressed-seal butterfly valves on order for Berkeley, the number of main gas valves supplied by us or in hand for atomic power reactors is now nearing the 100 mark. This is in addition to large numbers of valves for subsidiary circuits, circulating water service and conventional-type auxiliaries —amongst them a further 150 power operated valves in sizes up to 72 in. bore.

BLAKEBOROUGH

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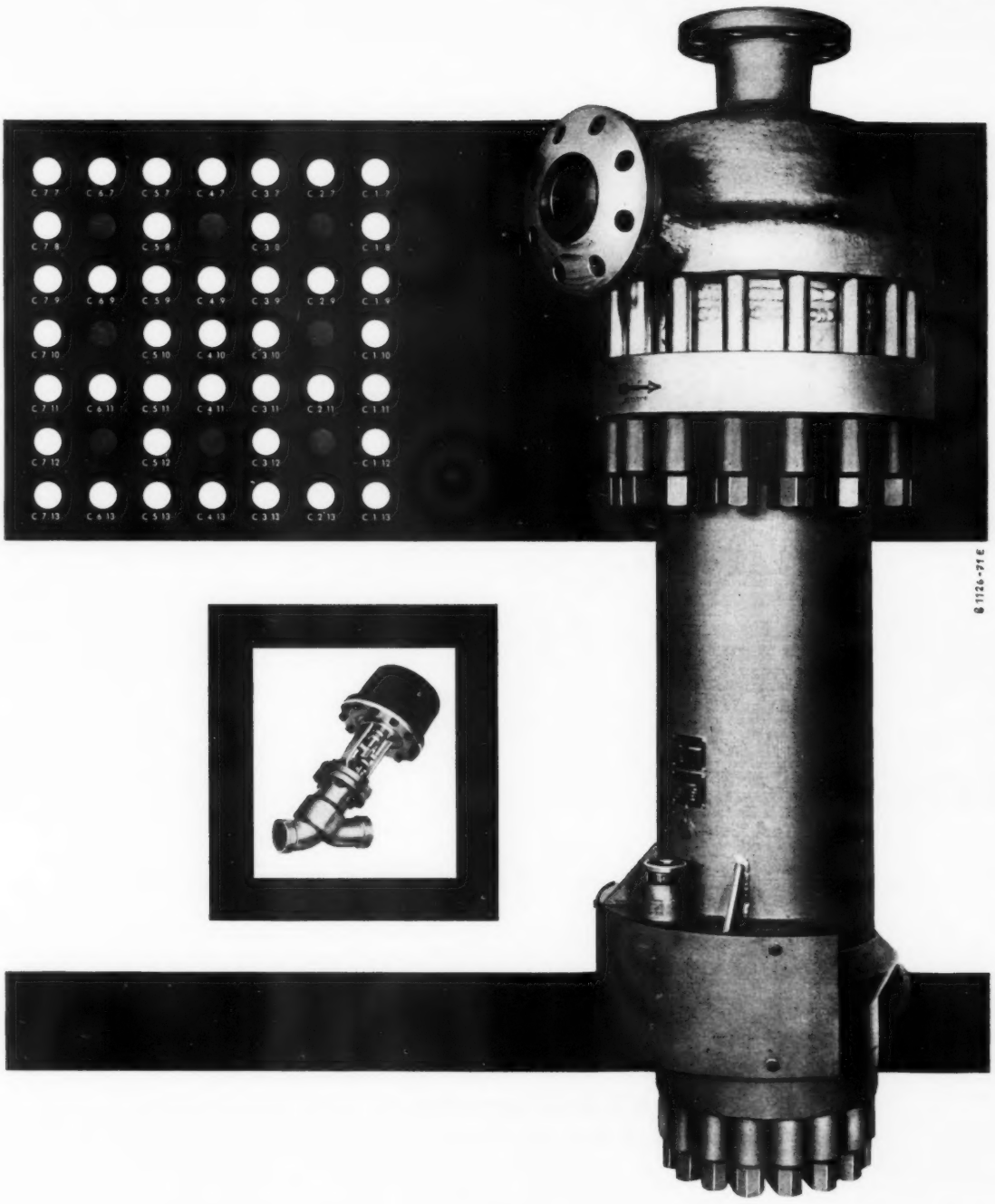

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For pressures and temperatures up to 3500 p.s.i.g. and 750° F (400° C). In our present range, maximum capacity and head 3700 GPM and 400 ft.

These Pumps are used for Forced Circulation Boilers, Nuclear Power Stations, special chemical processes and other industrial plants.

For CO_2 and Reactor Circuits where zero leakage is essential, we can supply "Bellows" type Valves of stainless steel with a moisture detector, suitable for all temperatures and pressures.

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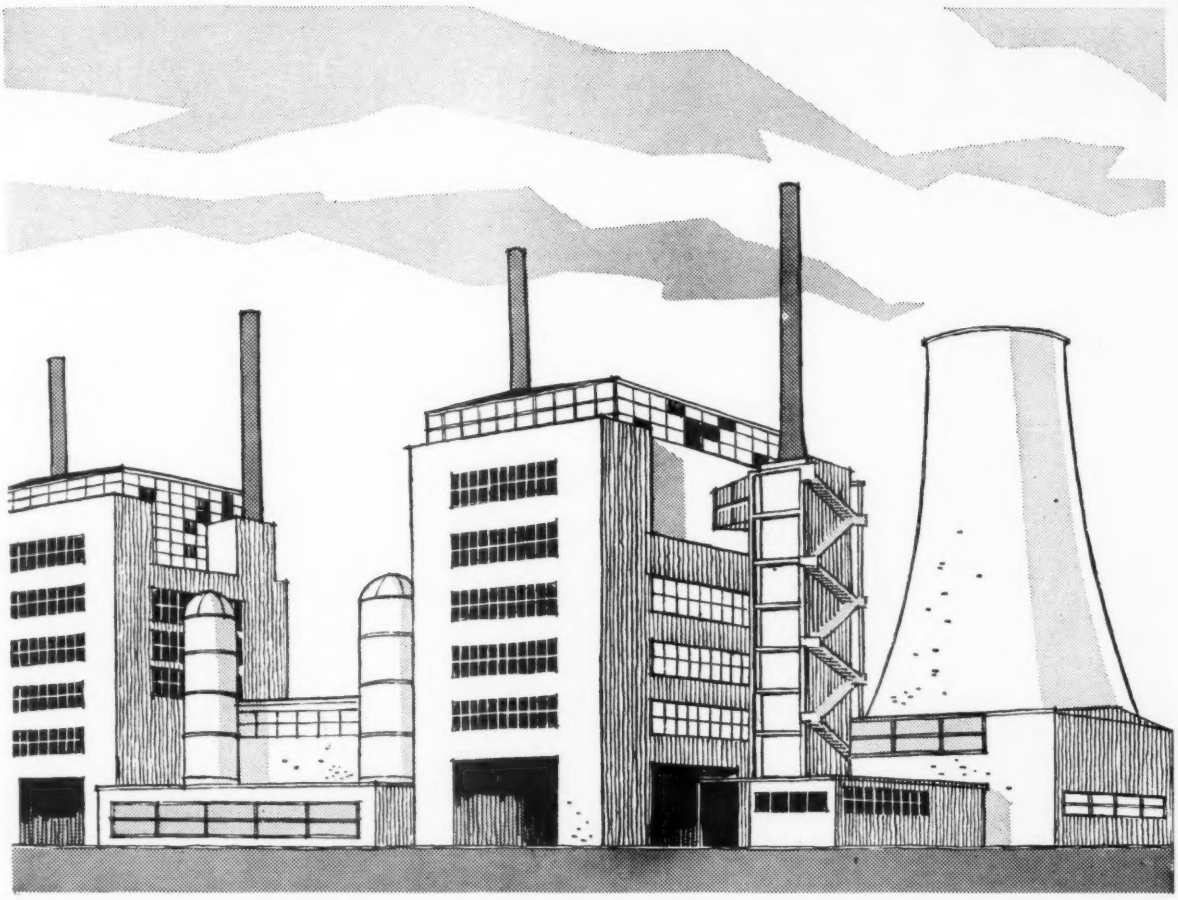

CROSSLEY ENGINES for Chapel Cross

Crossley Brothers have supplied the diesel engines for yet another nuclear power station. This time they are to provide standby electrical power for the United Kingdom Atomic Energy Authority's latest station—Chapel Cross.

Eight Crossley "HSN" six cylinder Scavenge Pump Diesel engines each supplying 500 kW through Brush generators, for automatic operation in the event of mains failure.

Crossley two-cycle Scavenge Pump Diesel engines have already been installed at Calder Hall and Dounreay, and are soon to enter service at Berkeley and Bradwell. They have been chosen to fulfil these vital duties because they are reliable diesel engines.

CROSSLEY DIESEL ENGINES

CROSSLEY BROTHERS LIMITED · OPENSHAW · MANCHESTER 11.

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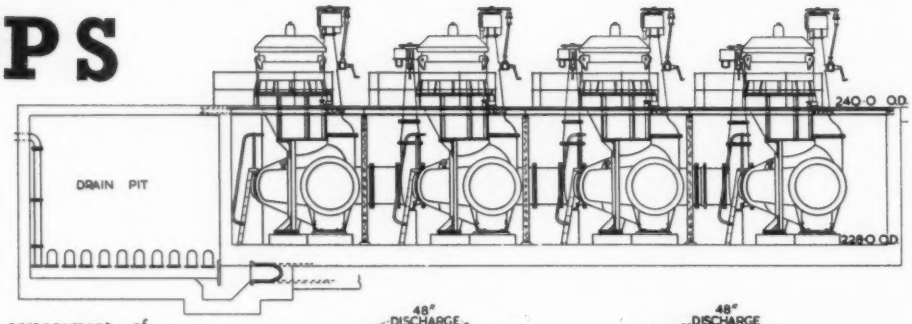
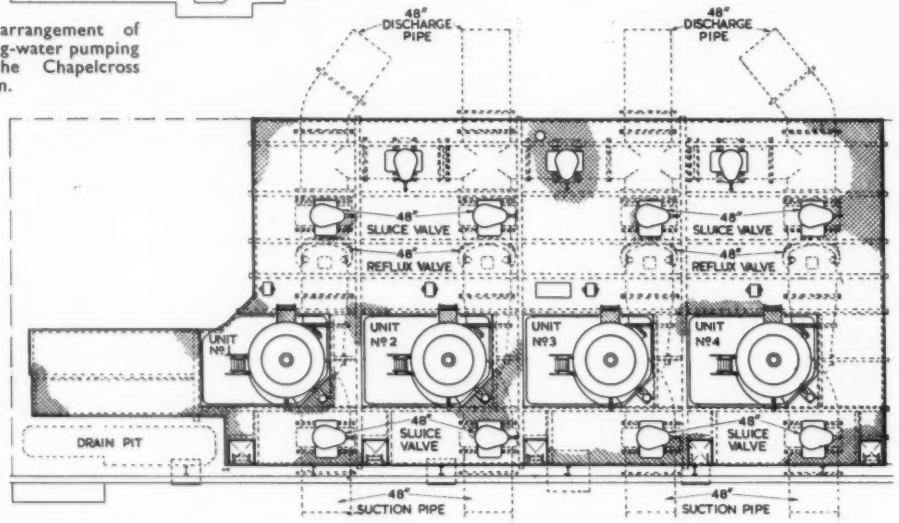
ALLEN CIRCULATING-WATER PUMPS





Installation arrangement of the circulating-water pumping units at the Chapelcross Power Station.

for the CHAPELCROSS POWER STATION of the UNITED KINGDOM ATOMIC ENERGY AUTHORITY

Consulting Engineers: MERZ AND McLELLAN

The installation comprises four Allen 48/48-in. vertical double-suction centrifugal pumps, each designed to deliver 50,000 gallons of water per minute against a total head of 67 feet, running at a speed of 490 r.p.m., and driven by a 1225-h.p. L.S.E. motor.

Allen centrifugal and mixed-flow pumps, horizontal or vertical, are designed to meet all requirements up to the largest capacity units needed in modern power station service.

Also for power station pumping applications, Allen-Stoeckicht patented double-helical epicyclic gearing offers a very compact and low-weight speed-reduction or speed-increasing arrangement to suit all powers and speed ratios.

Specialists in complete Pumping Plant installations

W. H. ALLEN SONS & Co LTD

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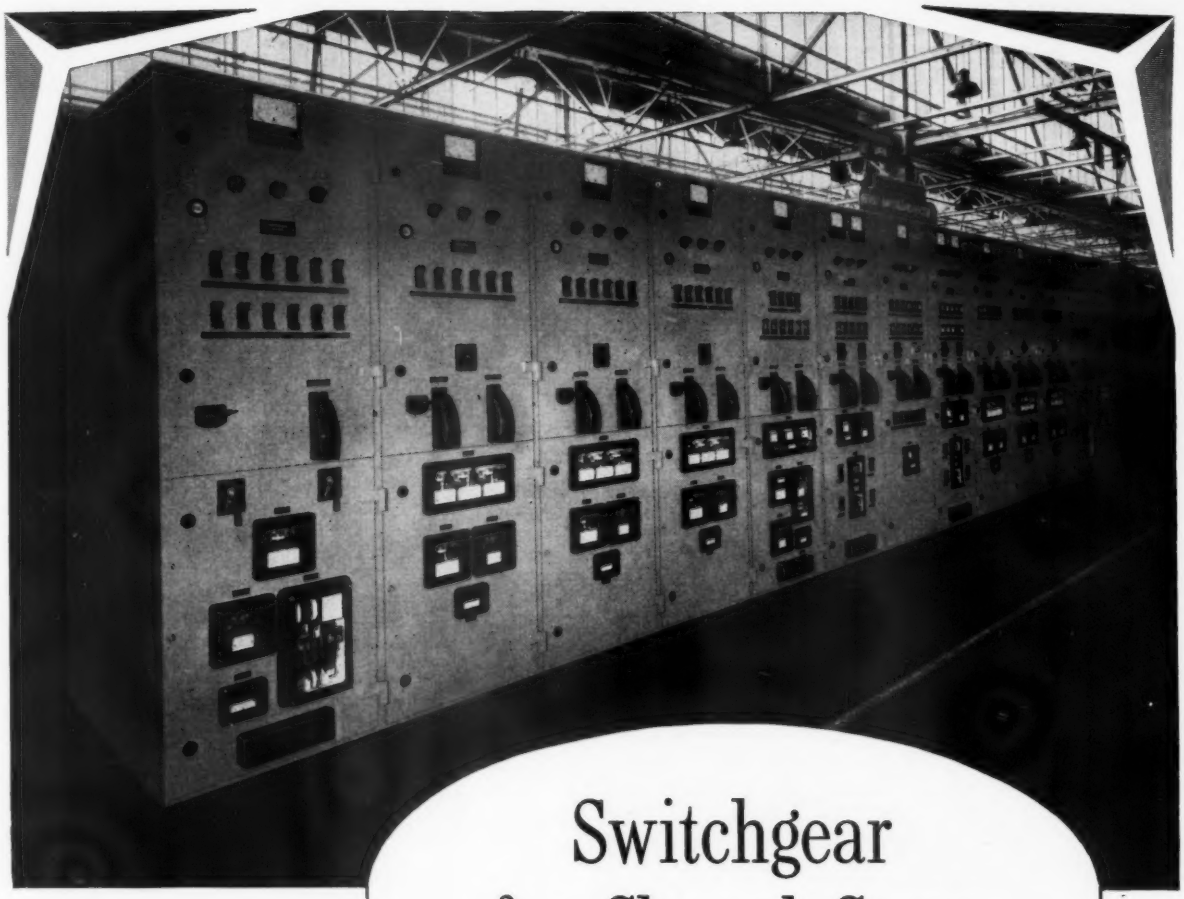

Switchgear for Chapel Cross

'ENGLISH ELECTRIC' switchgear similar to that supplied for the Calder Hall A and B stations will be installed in the atomic power station at Chapel Cross, Dumfriesshire. Four 350 MVA, 11kV switchboards incorporating metal-clad circuit-breakers will control the blower circuits associated with the heat exchangers of reactors 1, 2, 3 and 4. Four 3.3kV and eight 415 V air-break cubicle type switchboards will control the auxiliary power supplies for the turbine, pump and reactor houses, two of the 415 V boards feeding the reactor control rod generating sets.

'ENGLISH ELECTRIC'

THE ENGLISH ELECTRIC COMPANY LIMITED, MARCONI HOUSE, STRAND, LONDON, W.C.2

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PROGRESS

Britain has every reason to be proud of her achievements in the field of Atomic Energy for peaceful purposes.

The undoubted success of Calder Hall—the first large scale power producing unit in the world—has decided a pattern for the future. Already Stations much larger and more efficient are being built and CONSETT IRON COMPANY LIMITED is proud to have played an important part in both the initiation of Atomic Power and its further development.

The heart of the system is the Reactor itself and the plates for these vessels at Calder Hall and Chapelcross are made from Consett "CONLO" Steel, a highly notch tough easily weldable steel which has proved to be eminently suitable for jobs of such magnitude.

The Company does not stand still. At Bradwell the Reactors are being manufactured mainly from a specially developed low alloy steel, namely "BEARCOMO" which has the same ease of welding but a still further enhanced notch ductility coupled with increased resistance to creep at elevated temperatures. The Company, therefore, has the distinction of being the only supplier of an improved low alloy steel for the present programme. Yet again progress is not halted and extensive research is in being to provide Design Engineers with a still better steel which in turn will lead to increased efficiency.

Enquiries from Design Engineers and Authorities for details of these "HIGH DUTY PLATE STEELS" which are a speciality of the Company will be welcomed.

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LIMITED
CONSETT · CO. DURHAM · ENGLAND

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Photo, Walter Nurnberg, London.

FULL SCALE CAST PRODUCTION
Photo, Walter Nurnberg, London.

PLATE SPECIMENS UNDERGOING CREEP TESTS
Photo, Walter Nurnberg, London.

REACTOR DOME FOR CALDER HALL DESIGNED BY WHESSOE LTD.
Photograph by courtesy of Whessoe Ltd.

A44

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DO YOU BUY THE BEST ELECTRODES?

Which are the best welding electrodes? In the words of the philosopher, it all depends on what you mean by best. Best for your welders? Best for the job? Or best for your company? Best from the welder's point of view are electrodes giving ease of manipulation, speed of deposition, minimum spatter and easy slag removal. Best for the job are good mechanical properties, absence of undercut and welds of neat and regular appearance. Best from your company's point of view are high quality electrodes at a competitive price backed by good service.

When selecting the most suitable electrode for the job many engineers find it best to rely on their own practical experience and that is why most of them select the Murex "Fastex 5" electrode as the best general purpose electrode for the welding of mild steel.

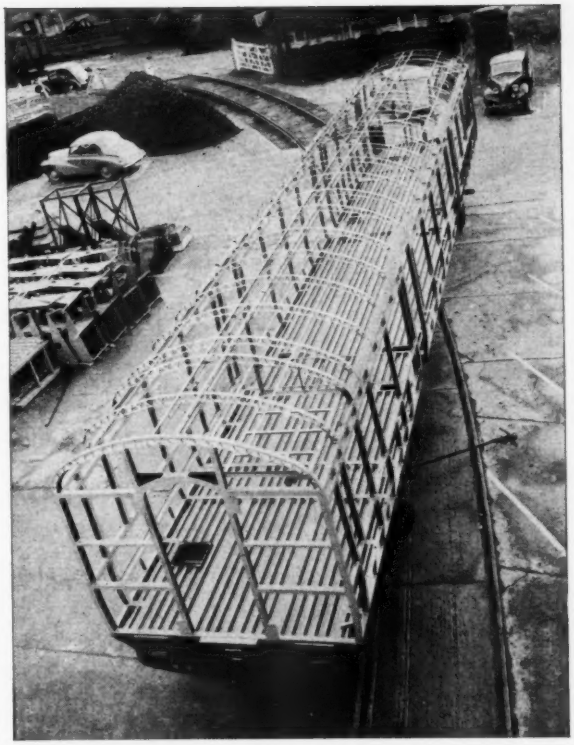
APPLICATIONS AND ADVANTAGES

The two main features which make the "Fastex 5" type the most popular electrode with welders are its smooth running properties and ease of operation. Added to these features are the advantages of self detaching slag and the very neat appearance of the weld deposit. The electrode is therefore eminently suitable for general fabrication work, particularly where horizontal fillet welding is required. The deposited metal can be hot forged.

There is little loss due to spatter and weld cleaning operations are reduced to a minimum. As a result of the correct distribution of heat between molten slag and weld metal the control of weld contour is easily obtained when using heavy gauge electrodes so that comparatively small fillet welds can be made with consequent saving in the cost of production.

The 14 S.W.G. electrode is particularly suitable for welding light gauge sheet metal, especially for making fillet welds. Also as touch welding is relatively easy to carry out, the "Fastex 5" electrode is an ideal type for initial training in welding.

Although primarily designed for flat and horizontal vertical welding, the "Fastex 5" electrode can be used in other positions. This is why it is so useful as a general purpose electrode for so many different applications. It is also fully approved by all the main approval authorities. In short, it is the best electrode for most jobs.



A typical application of Murex "Fastex 5" electrodes. An all-welded integral body frame of a multiple unit diesel train designed and built by D. Wickham & Company Limited, Ware, Herts.

APPROVALS — Approved by the Admiralty for use on mild steel and DW quality steel in all positions.

Approved by Lloyd's Register of Shipping for use in all positions.

Accepted by the Ministry of Transport for use in all positions.

Approved by Ministry of Supply, F.V.R.D.E. Specification 1050/1V.

Approved by the American Bureau of Shipping for use on mild steel in all positions.

Approved by Det Norske Veritas for use in all positions.

Complies with B.S. 639:1952 Parts 1 and 2, and B.S. 538:1940.

The electrode also complies with the requirements of A.I.D.

"FASTEX 5"—the best electrode for most jobs

MUREX

MUREX WELDING PROCESSES LTD., Waltham Cross, Herts. Tel: Waltham Cross 3636

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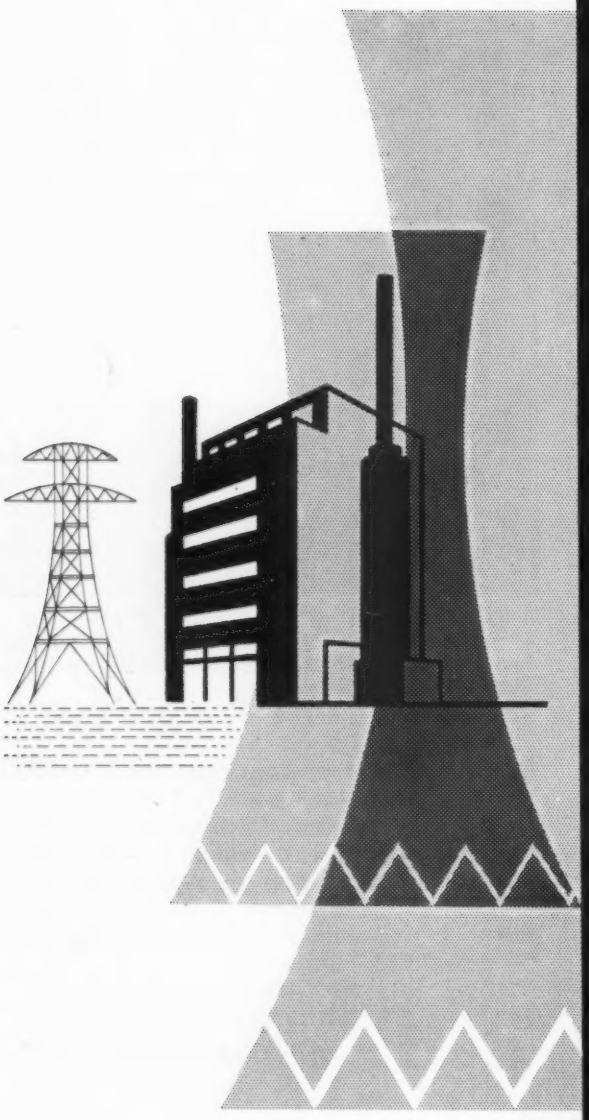

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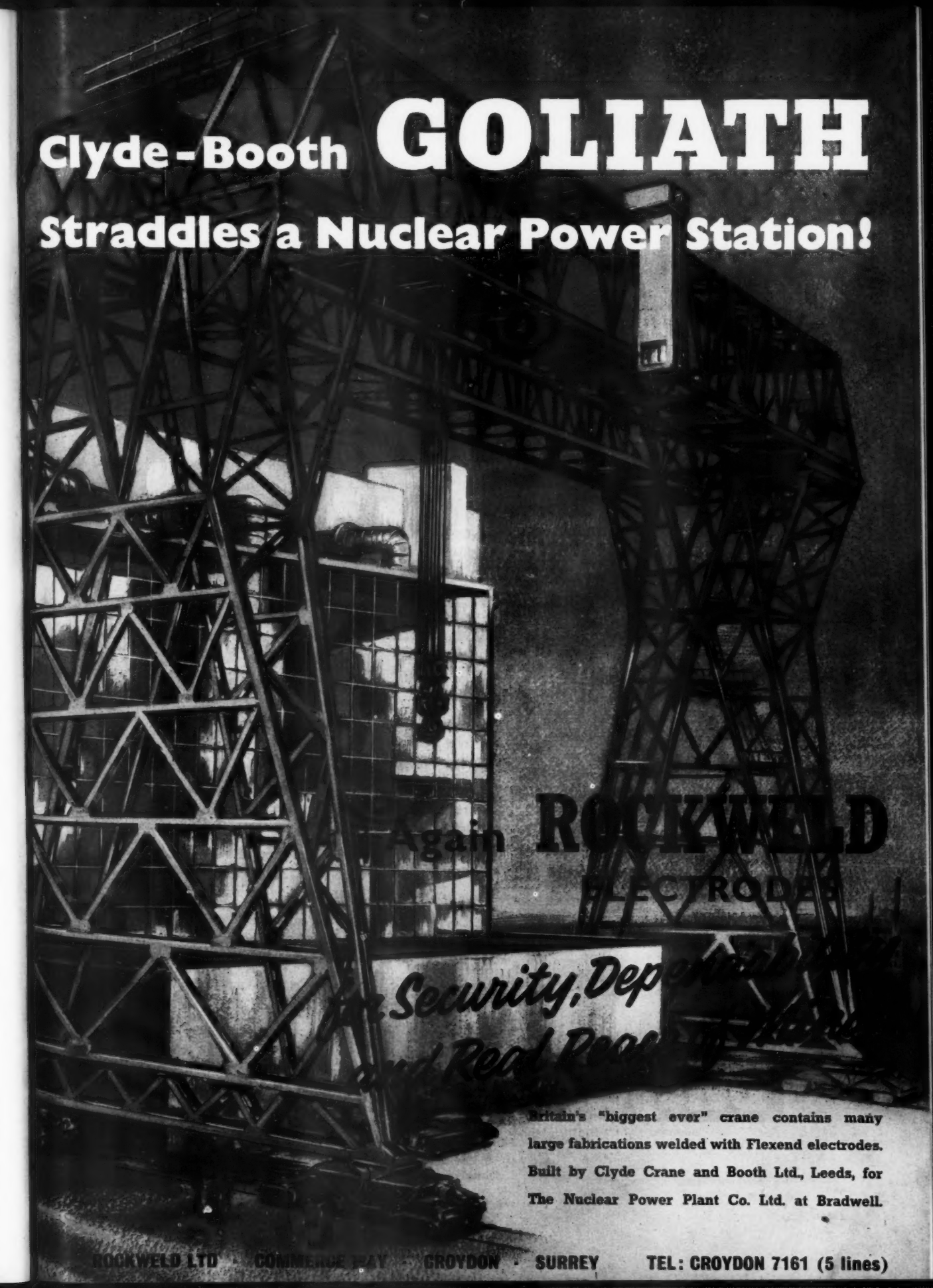
Straddles a Nuclear Power Station!



Britain's "biggest ever" crane contains many large fabrications welded with Flexend electrodes. Built by Clyde Crane and Booth Ltd., Leeds, for The Nuclear Power Plant Co. Ltd. at Bradwell.

ROCKWELD LTD · COMMERCE WAY · CROYDON · SURREY TEL: CROYDON 7161 (5 lines)

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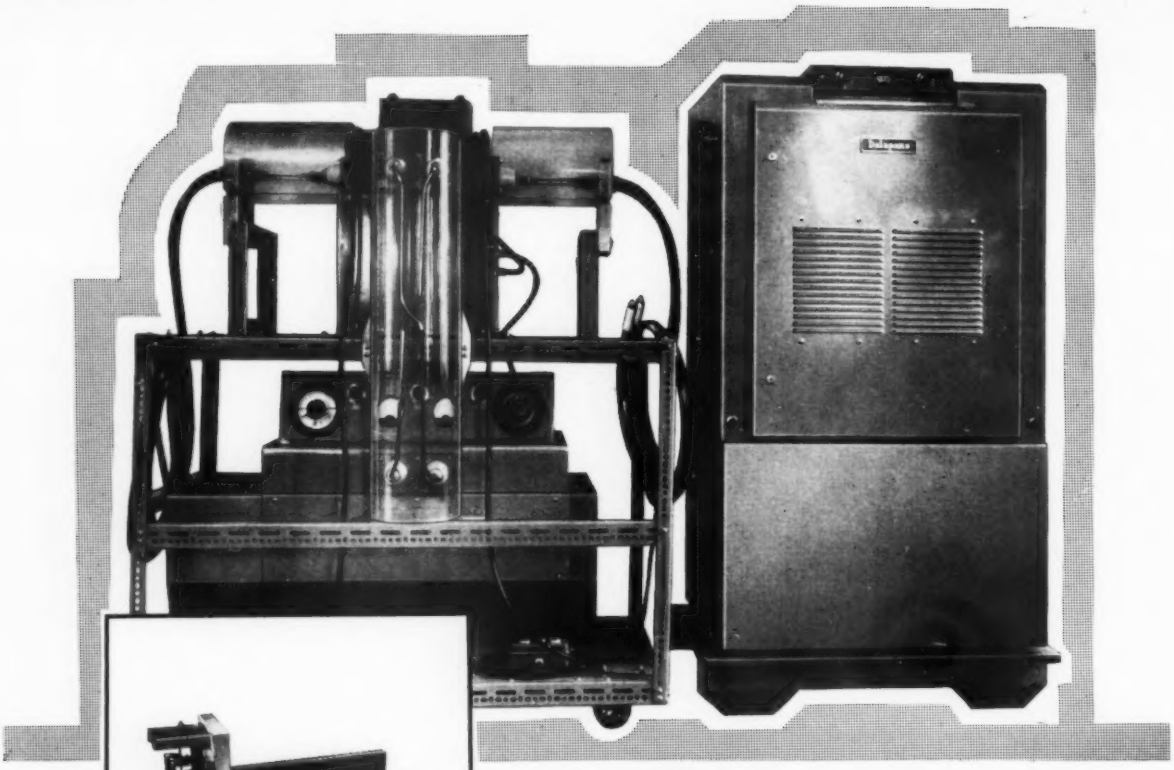

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perform "the impossible"

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Nuclear power stations all over the British Isles and Europe are relying for this important task, on Delapena equipment. Here are some of the reasons.

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- ★ Delapena equipment is preferable to welding or mechanical jointing, especially where limited working space is available, and there are no locking and sealing problems.
- ★ Delapena equipment works fast—more than 250 joints can be completed in a day.
- ★ Delapena equipment is accurate. Rejection rate is, on the average, around ·5%.

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is specified for

Nuclear Projects

because of its

Flexibility and Simplicity

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WHERE COST COUNTS IT'S COLES.

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COLES THE NAME THAT CARRIES WEIGHT

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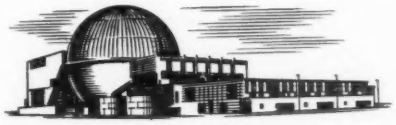
facing new fire problems in the sphere of nuclear power



The Pyrene Company, with its unrivalled facilities for research, keeps ahead of changing industrial techniques, and is constantly developing the means to overcome the new fire risks they involve. As makers of the world's most comprehensive range of fire-fighting equipment, The Pyrene Company can give you invaluable and impartial advice on any fire protection problem—it is yours for the asking.

We are proud to have given advice on fire protection—and supplied major fire-fighting equipment—for most British atomic centres already constructed. Consult Pyrene Fire Engineers and ensure maximum fire protection for valuable plant and human lives too.

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P1977

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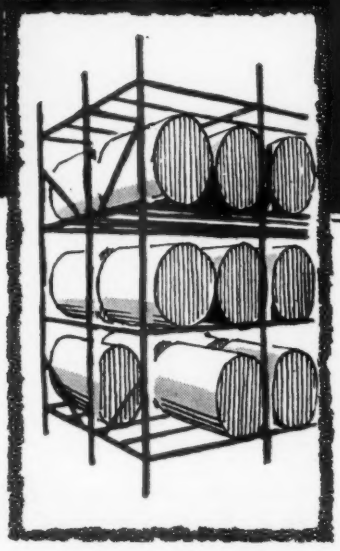

UNISTRUT

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SPEED AND ECONOMY IN PURPOSE-MADE SUPPORT STRUCTURES

Unistrut components—steel channel for framing and a comprehensive range of specific-purpose components—are standardised round a brilliantly simple, ultra-rapid self-locating nut assembly. Whatever the requirements of the individual job, Unistrut enables you to build a correct, economical support structure *at the minimum on-site cost*. It's a matter of fundamental design. Please write for details to the address below.

FOR RACKING, PIPING AND ELECTRICAL INSTALLATIONS, AND ALL FRAMING APPLICATIONS

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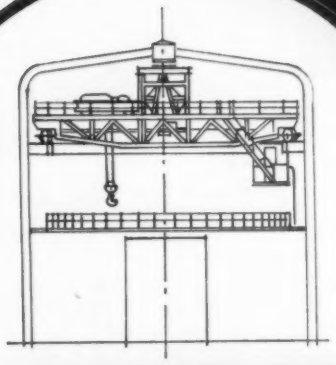
UNI 9750

CRANE MAKING
In the Atomic field



DIDO — PLUTO

In collaboration with the Ministry of Works Engineering Staff we designed and installed a special form of circular motion Overhead Electric Travelling Crane, for operation in Britain's first experimental Reactor at Harwell.

Further circular motion units have been installed at both Harwell and Dounreay, the latter on instructions from the United Kingdom Atomic Energy Authority.

Shortly we will commission a similar crane for the Australian Atomic Energy Commission.

The cranes are designed for a lift of 25 tons on a span of approximately 67 ft.

We are currently engaged in the installation of Main Turbine House and Blower House Cranes for Calder "B" and Chapelcross Atomic Power Stations.

THE WHARTON CRANE & HOIST CO. LTD.

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SCOTLAND: Fisher-Baxter & Co., 140 West George Street, Glasgow C.2.	Phone: Douglas 1061–2–3.	Grams: Fluorspar, Glasgow.
MIDLANDS: A. R. Holland & Son, 89 Cornwall Street, Birmingham 3.	Phone: Central 1457.	Grams: Central 1457, Birmingham.
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NORTHERN IRELAND: General Engineering Products Ltd., 7/9 Great Patrick Street, Belfast.	Phone: Belfast 23743.	Grams: Belfast 23743.
REPUBLIC OF IRELAND: Charles Nolan & Co., 2 Parker Hill, Lower Rathmines Road, Dublin.	Phone: Dublin 93510.	Grams: Dublin 93510.
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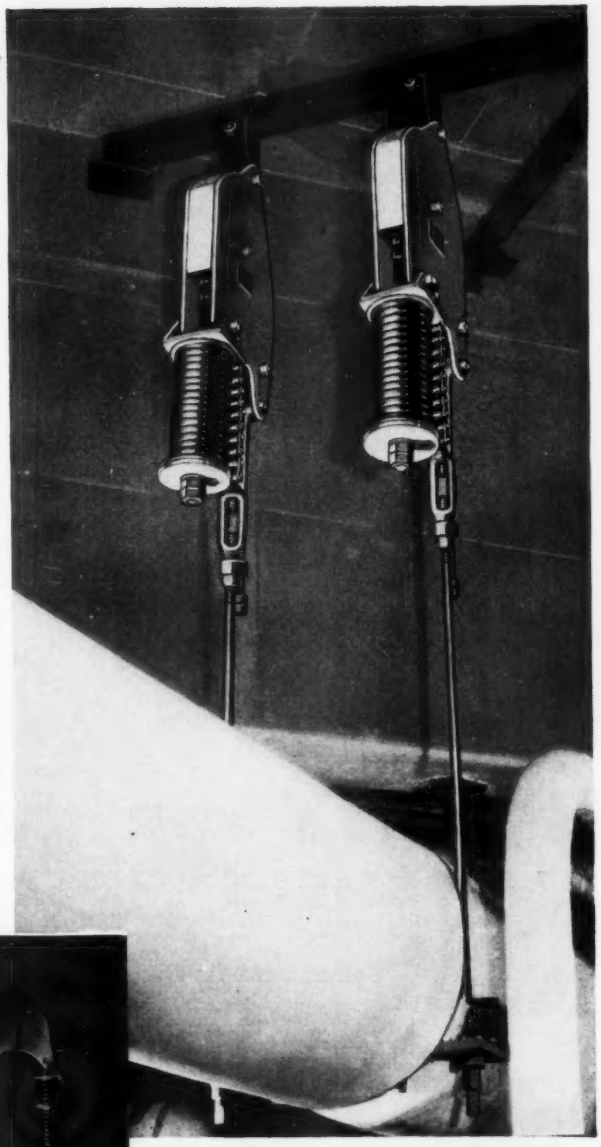
constant tension supports

FOR LOADS UP TO 8 TONS
PIPE MOVEMENTS UP TO 18″

High-pressure steam piping is subject to wide variations in temperature, which produce considerable expansion and contraction. Unless the pipe supports can absorb and compensate for this movement, severe stresses are set up which may result in fracture. The "Con-Ten" Pipe Support is designed to cradle any type of piping with constant tension under all conditions, throughout the range of movement. "Con-Ten" is installed, with eminently satisfactory results, in power stations, oil refineries, chemical and industrial plants throughout the world.

British Patent No. 474008, 720074, 720075, 697987, 65318
U.S.A. Patent No. 2129320



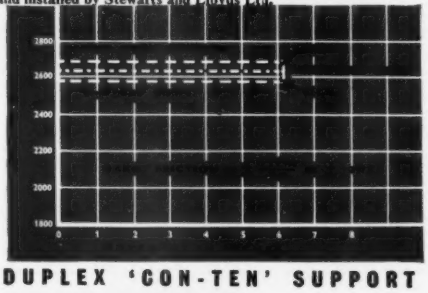
Ferrybridge 'B' Power Station, Central Electricity Generating Board, Yorkshire Division. H.P. Steam pipes supplied and installed by Stewarts and Lloyds Ltd.

Leibfried Red Top Pipe Supports for load from 100 to 5,000 lbs. and total travel of 3″.

Conventional type "Con-Ten" Supports for loads of up to 2 tons with a total vertical movement up to 12″.

Duplex "Con-Ten" Supports for load of up to 8 tons with a total vertical movement up to 12″. This type is acknowledged as one which produces minimum friction and kinematic variation. It has been specially designed for any applications where exceptional accuracy is demanded,

From graph it can be seen that the maximum friction is equivant to 2.17% of the applied load.



DUPLEX 'CON-TEN' SUPPORT

BRITISH INDUSTRIAL

ENGINEERING COMPANY (STAFFS) LIMITED

CORONATION WORKS, HAINGE ROAD, TIVIDALE, TIPTON, STAFFS.

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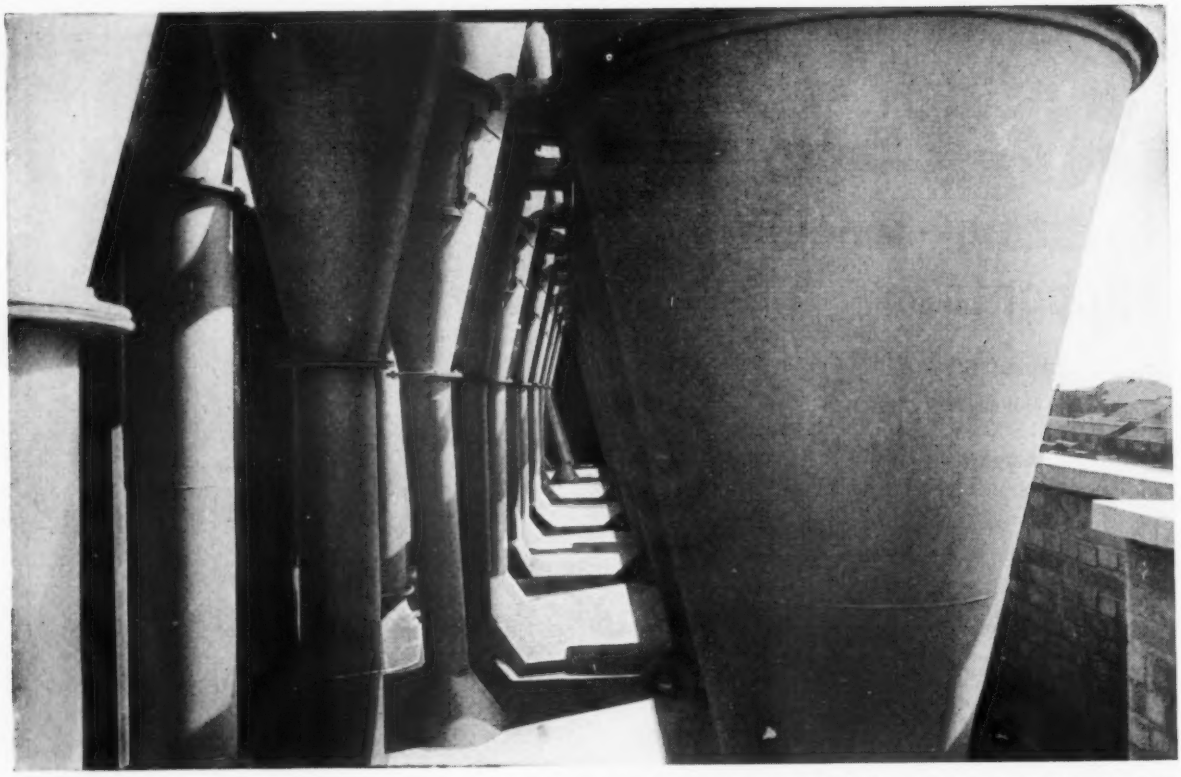
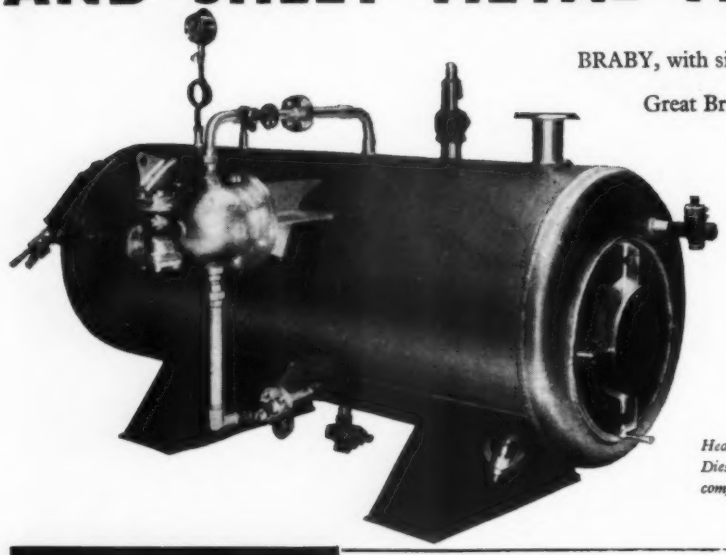


Mild Steel Plate Cyclones and Ducting supplied and erected at large Cattle Feed Mill in London.

BRABY FOR METAL PLATE AND SHEET METAL FABRICATIONS



BRABY, with six factories located in widely separated parts of Great Britain, have, for more than 100 years specialised in Metal Plate and Sheet Metal Work. The technical knowledge and experience of our Staff and the employment of a labour force of skilled craftsmen, enables us to provide for Industry an efficient Metal Plate and Sheet Metal Work manufacturing service.

Heat Recovery Exhaust Silencer Boiler utilising heat from Diesel engine exhaust. Made by BRABY for their subsidiary company, Maxim Silencers Limited.

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Ashton Gate Works, Bristol, 3. TELEPHONE: Bristol 64041. And Falkirk

OTHER OFFICES: 110 Cannon Street, London, E.C.4 (Export). TELEPHONE: MANsion House 6034
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AP 89

Right from the start

BUTTERS CRANES

have been used on every one of the Nuclear Power Stations built or building in Britain.

At Calder Hall, Chapelcross, Dounreay, Hinkley Point, Berkeley and Bradwell considerable numbers of Butters Derricks were engaged or are in service at this moment.

The latest development is the use of Butters Monotower Cranes at Berkeley, as illustrated above. For the erection of the reactors and general construction four 15-ton Monotowers have been installed and the capability of these cranes is well shown in the photograph.
Each crane is of the fixed type, electric, with three motors; the towers are 120 ft. high and the jib 127 ft. 6 ins. long. The maximum load of 15 tons is handled at 90 ft. radius, while 6 tons can be lifted at 125 ft. radius.

BUTTERS BROS. & CO. LTD.,

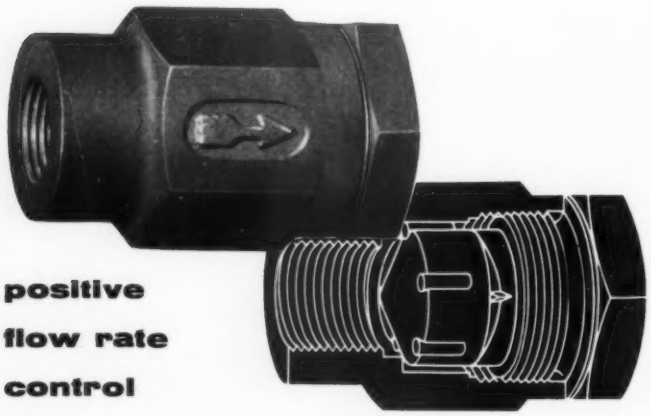
MACLELLAN STREET, GLASGOW, S.1

AND AT LONDON, BIRMINGHAM AND NEWCASTLE

BIRFLO controls

for positive and precise
regulation of hot or cold water,
light oils and air.

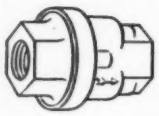
Constaflo CONTROL



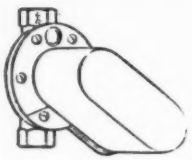
positive flow rate control for water-oil-air

The "Constaflo" is designed to deliver one set rate of fluid flow regardless of variable inlet pressures between 10-200 lbs. p.s.i. It automatically measures a predetermined amount of flow regardless of variable pressures and eliminates unnecessary waste. A fixed rate of outlet flow is assured as the flow is regulated in direct proportion to the inlet pressures exerted against the diaphragm. The "Constaflo" is available in three sizes, to cope with rates of flow from ·1 to 7 g.p.m., it is of high quality non-corrosive bronze, and is both durable and reliable. The "Constaflo" can be used with a timing device for measuring quantities, subdues pressure hammer and flow surges, and reduces maintenance of appliances and equipment.

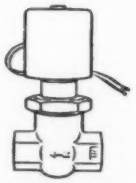
The "Constaflo" is one of seven Birflo controls, each designed to solve flow problems.



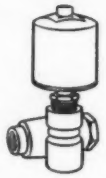
MULTI CONSTAFLO
An accurate metering valve for flow rates up to 18 g.p.m. Sizes ¾" & 1"



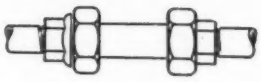
TRUFLO
For positive flow-rate control with minimum (0·1 g.p.m.) or maximum (40g.p.m.) limits.



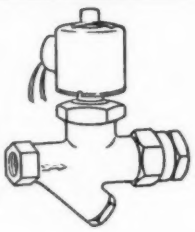
FLOMAX
A solenoid valve for maximum flow rates. Sizes up to 1¼" B.S.P.



FLOMITE
A direct acting solenoid valve for small flow and volume control. Sizes ¼" and ⅜"



STRAITFLO
A straight line strainer, installed in the supply, having the entire strainer area within the flow way itself. Sizes up to 1¼"



FLOMETRIC
A compact assembly of solenoid valve, flow rate control and inlet strainer. Rates up to 4·5 g.p.m.

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Fully informative leaflets on all the Birflo Controls are available on request.

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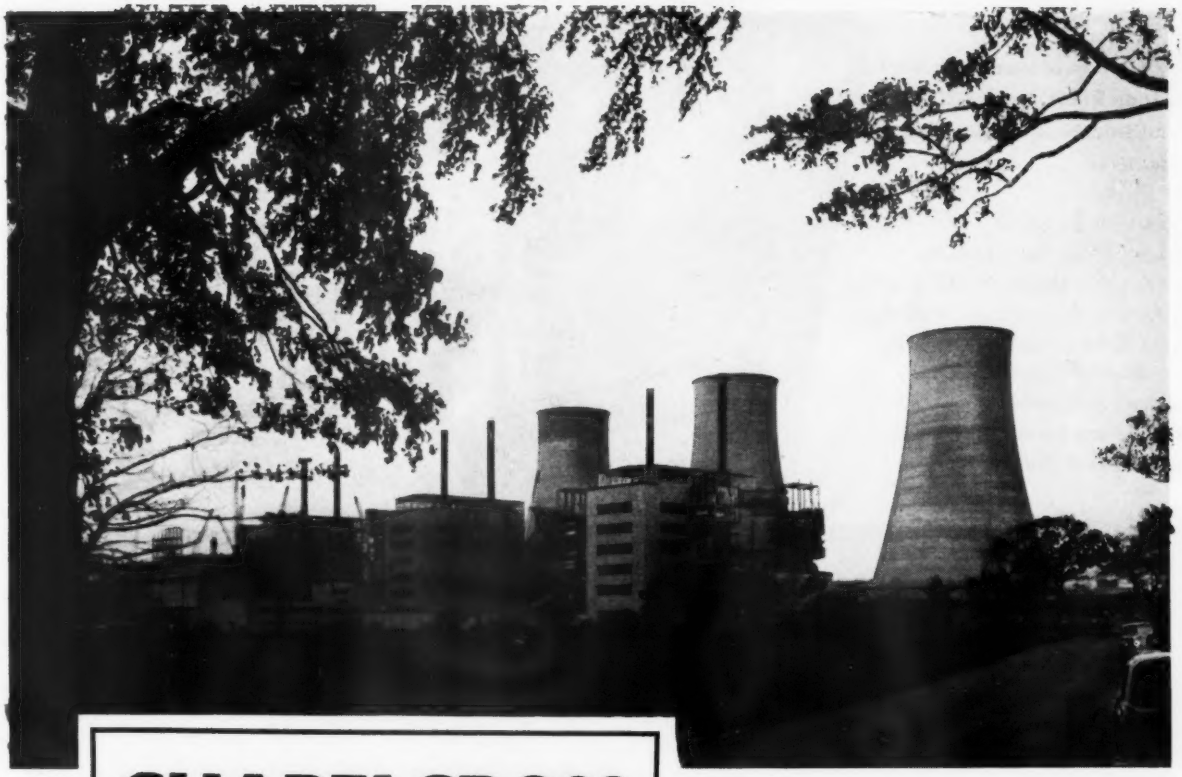


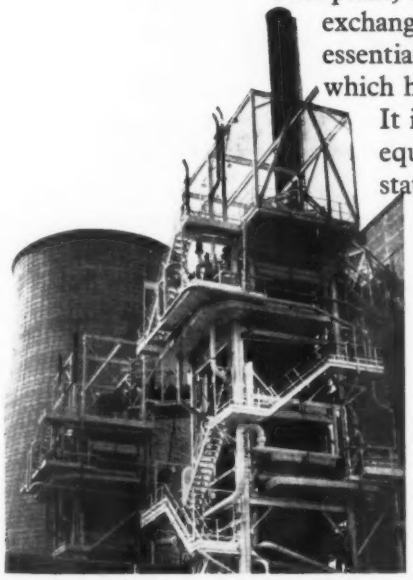
CHAPELCROSS

BABCOCK & WILCOX LIMITED have been responsible for the design, manufacture and installation of all the steam-raising plant for the new Chapelcross atomic power station.

This plant, comprising 16 steam-raising units (heat-exchangers) of the Babcock dual-pressure type, is essentially a duplicate of that at Calder Hall, which has been in successful service since 1956.

It is indeed the prototype of the steam-raising equipment for all the much larger atomic power stations now under construction in Great Britain.

Babcock equipment at Chapelcross includes also a number of Goliath and other cranes, travelling platforms, etc. for spent-fuel handling and other services.



BABCOCK

ATOMIC POWER PLANT

BABCOCK & WILCOX LIMITED, 209 EUSTON ROAD, LONDON, N.W.I.

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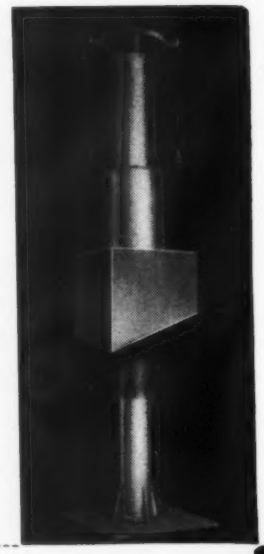
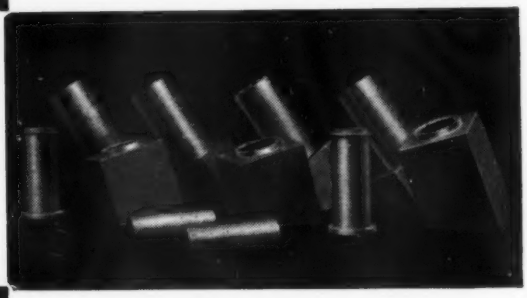
We are equipped with Weld X-Ray Plant, materials testing and microscopic examination facilities

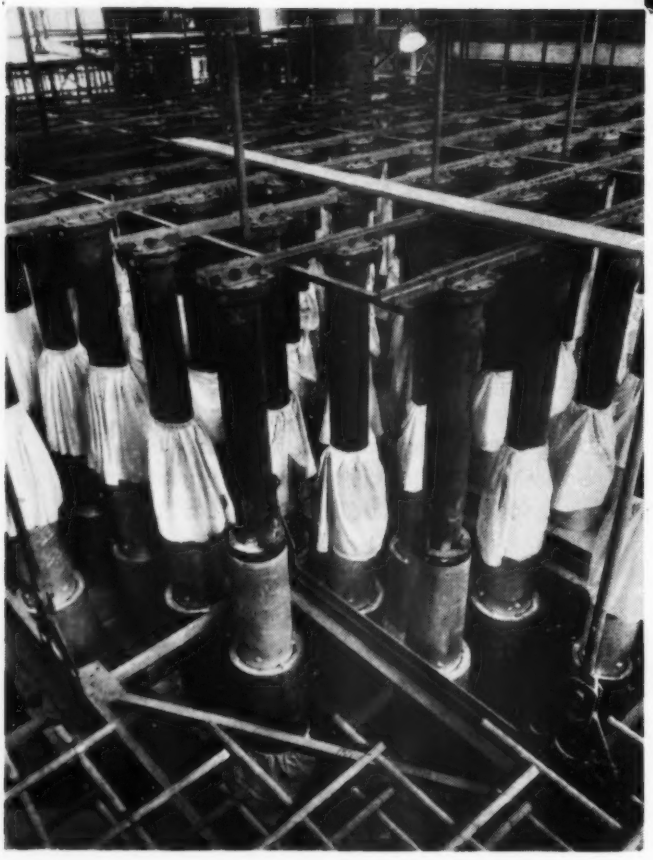
ILLUSTRATED
(right) Hood Tube Assembly undergoing alignment and accuracy testing in the Butterfield workshops (far right) Component parts for Irradiation Tubes and Liners (below) Irradiation Hood Tubes and Liners during construction at the Power Station



AS FABRICATORS to the United Kingdom Atomic Energy Authority Butterfields are proud to have supplied Irradiation Hood Tubes and Liners for the **Chapelcross Atomic Power Station.** Butterfield craftsmen work to the high standards demanded by this very important work fabricating in Stainless Steel, Mild Steel, Aluminium, "Monel," Nickel etc.

Butterfield





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such as we have supplied for the following atomic power stations

BERKELEY 2 CHARGE FACE CRANES

BRADWELL 40-TON GOLIATH

DOUNREAY CHARGE FACE CRANE

HUNTERSTON 2 40-TON GOLIATHS

Within fifteen years Carruthers Cranes have built for themselves a world wide reputation for efficiency and reliability.
Although the business was established in 1887 mainly for the manufacture of pumps and land auxiliaries, it was only in 1943 that their activities were expanded to embrace the design and production of Cranes. Today every Carruthers Crane is designed with liberal factors of safety and wear to meet specific site and service conditions.

You are invited to consult our design staff on any handling problem.

carruthers

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London Office : Abford House · Wilton Road · Victoria S.W.1

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THE PEACEFUL ATOM

New development will provide low-cost power for Europe

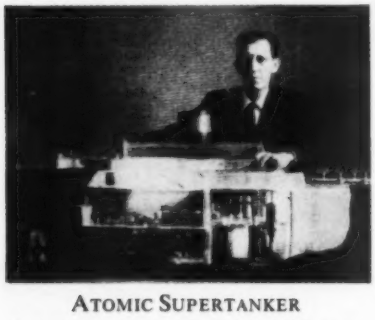
Organic Moderated Reactor Offers Improved Efficiency for both Large and Small Nuclear Power Plants

From misty fjord to sun-drenched vineyard . . . from snowy alp to storm-beaten coast . . . Europe is a continent of contrasts. Local conditions vary widely, from one region to the next. Yet Europe shares a common destiny: it is embarked upon a new industrial revolution. To feed this new surge of progress Europe needs new power—power that is not dependent on dwindling fuel supplies.

Atomics International now brings news of a nuclear reactor to meet the power demands of Europe—a reactor that is ideally suited for European manufacture and operation.

Results exceed expectations

This latest power reactor to be successfully developed by Atomics International is the Organic Moderated Reactor. A fully functioning prototype has been in operation since September, 1957. Performance of this Organic Moderated Reactor Experiment has exceeded design expectations, and has demonstrated the readiness of this reactor type for power plant application. The U. S. Atomic Energy Commission, for whom Atomics International designed and built the reactor, has authorized negotiations for construction of the first Organic Moderated Reactor power station for the American city of Piqua, Ohio. Other plans are under way.



ATOMIC SUPERTANKER

A nuclear-powered ship would carry more payload for longer hauls, and need refueling less than once a year.

Economical to build and operate

The Organic Moderated Reactor is a straightforward, low-pressure system, inherently safe, using conventional structural materials such as carbon steel and aluminium. Negligible corrosion factors, easy access, and use of standardized fittings and components mean low-cost maintenance. Capital investment and operating costs are minimized.

Design and cost information on Organic Moderated Reactor power stations of various sizes is available from Atomics International.

For merchant ships

Another promising application of the Organic Moderated Reactor is ship propulsion. Design and cost studies on supertanker operation have been made.

Associates in Europe

In association with the prominent West German manufacturing company DEMAG, Atomics International has formed the jointly owned subsidiary INTERATOM, headquartered in Duisburg. We also have a technical assistance agreement with ASEA of Vasteras, Sweden, the international electrical firm with offices in 50 countries. For more information, please contact ATOMICS INTERNATIONAL, Canoga Park, California, U. S. A. Cable address: ATOMICS.

SUCCESSFUL PROTOTYPE

The Organic Moderated Reactor Experiment in Idaho, U. S. A. Plans for an OMR power station are under way.

ATOMICS INTERNATIONAL

A DIVISION OF NORTH AMERICAN AVIATION, INC.

PIONEERS IN THE CREATIVE USE OF THE ATOM

Other Offices in: Washington, D. C., U. S. A.; Geneva, Switzerland
Affiliated with: Interatom, Duisburg, West Germany

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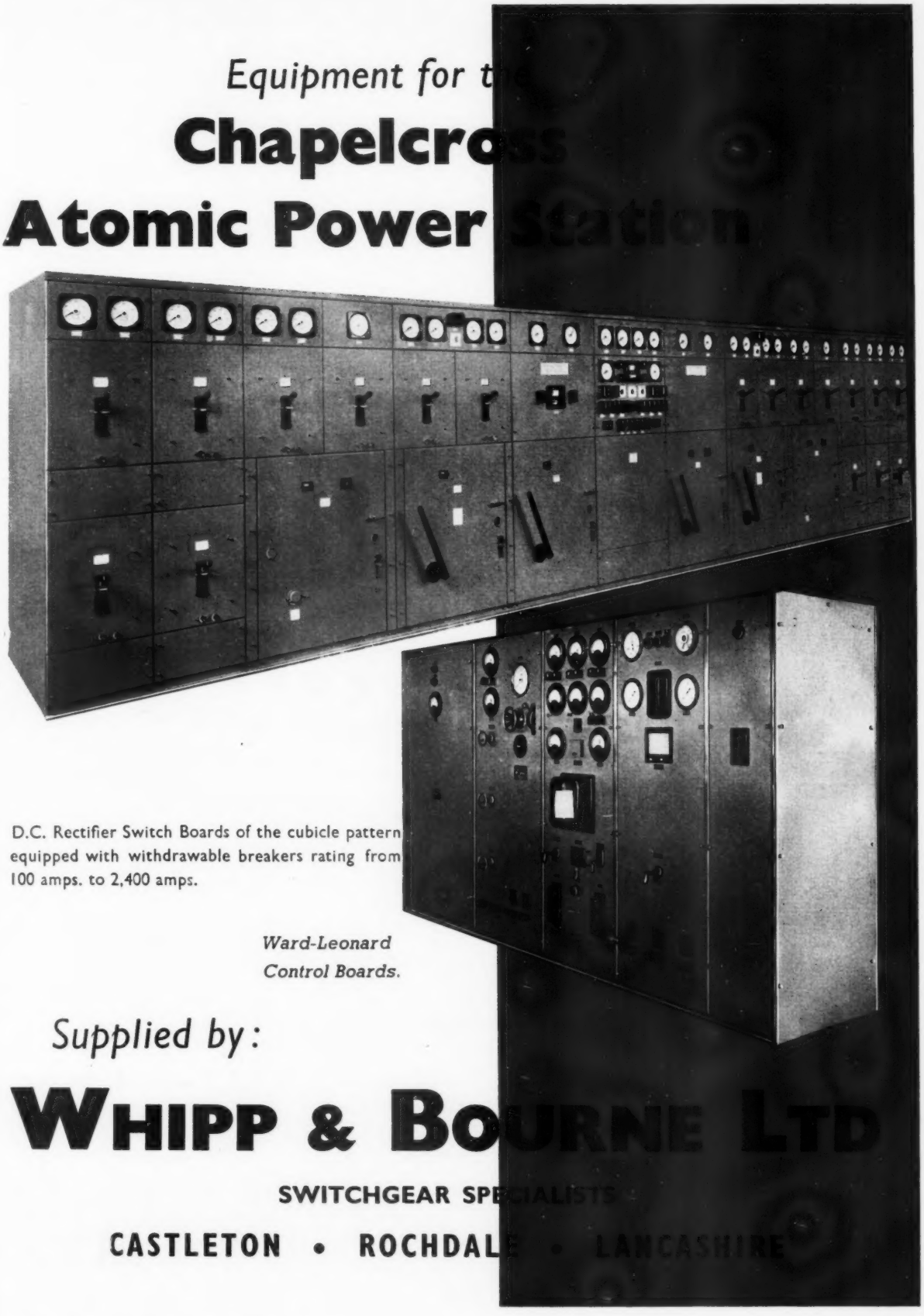
Equipment for t

Chapelcro
Atomic Power Station



D.C. Rectifier Switch Boards of the cubicle pattern equipped with withdrawable breakers rating from 100 amps. to 2,400 amps.

Ward-Leonard Control Boards.

Supplied by:

WHIPP & BO URNE LTD

SWITCHGEAR SPE CIALISTS

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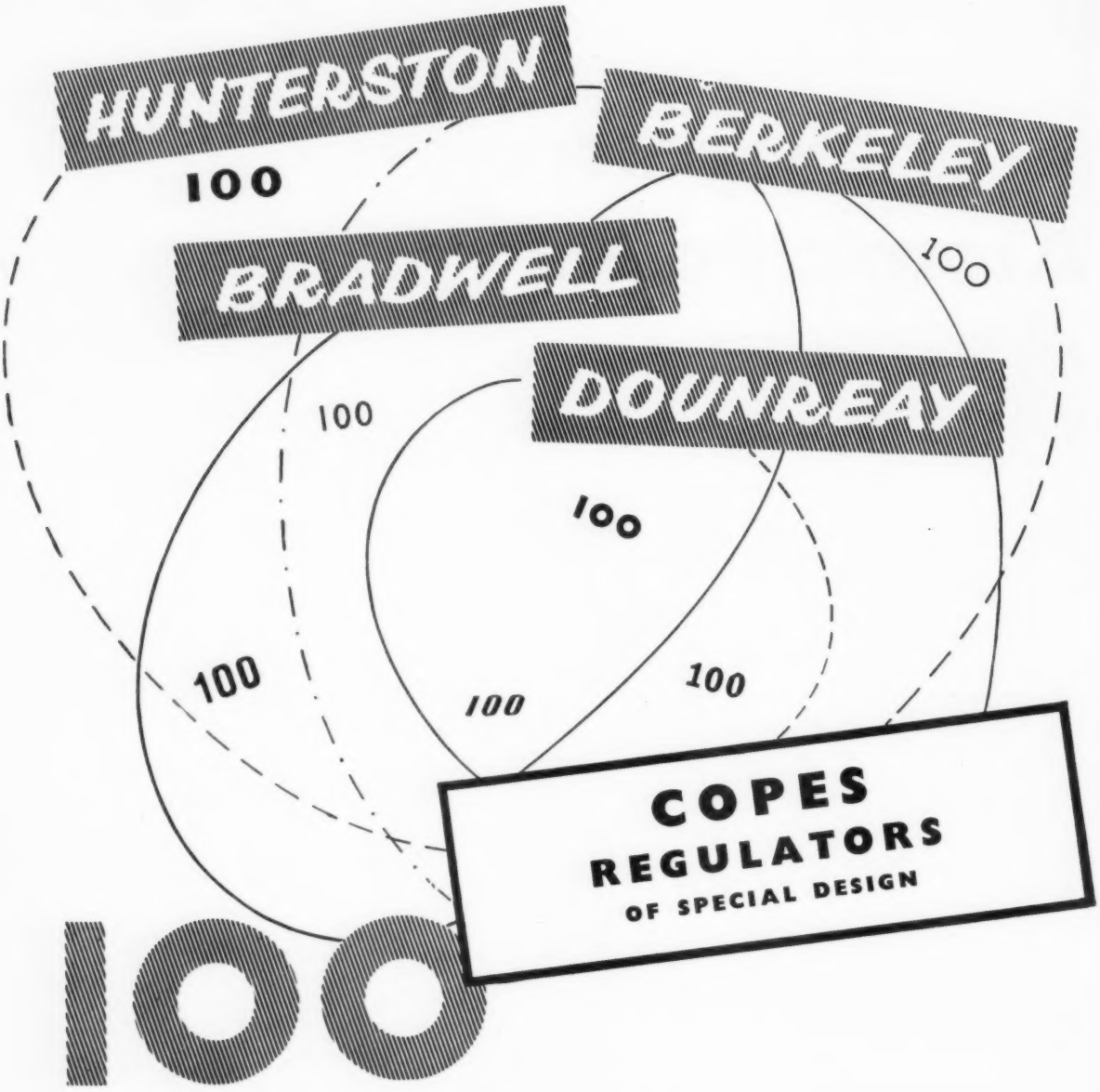

HAVE BEEN ORDERED FOR THE ABOVE NUCLEAR POWER PLANTS

COPES FEED CONTROL ENSURES THE CORRECT RATE OF FEED WATER FLOW UNDER ALL LOAD CONDITIONS

COPES

COPES REGULATORS LTD

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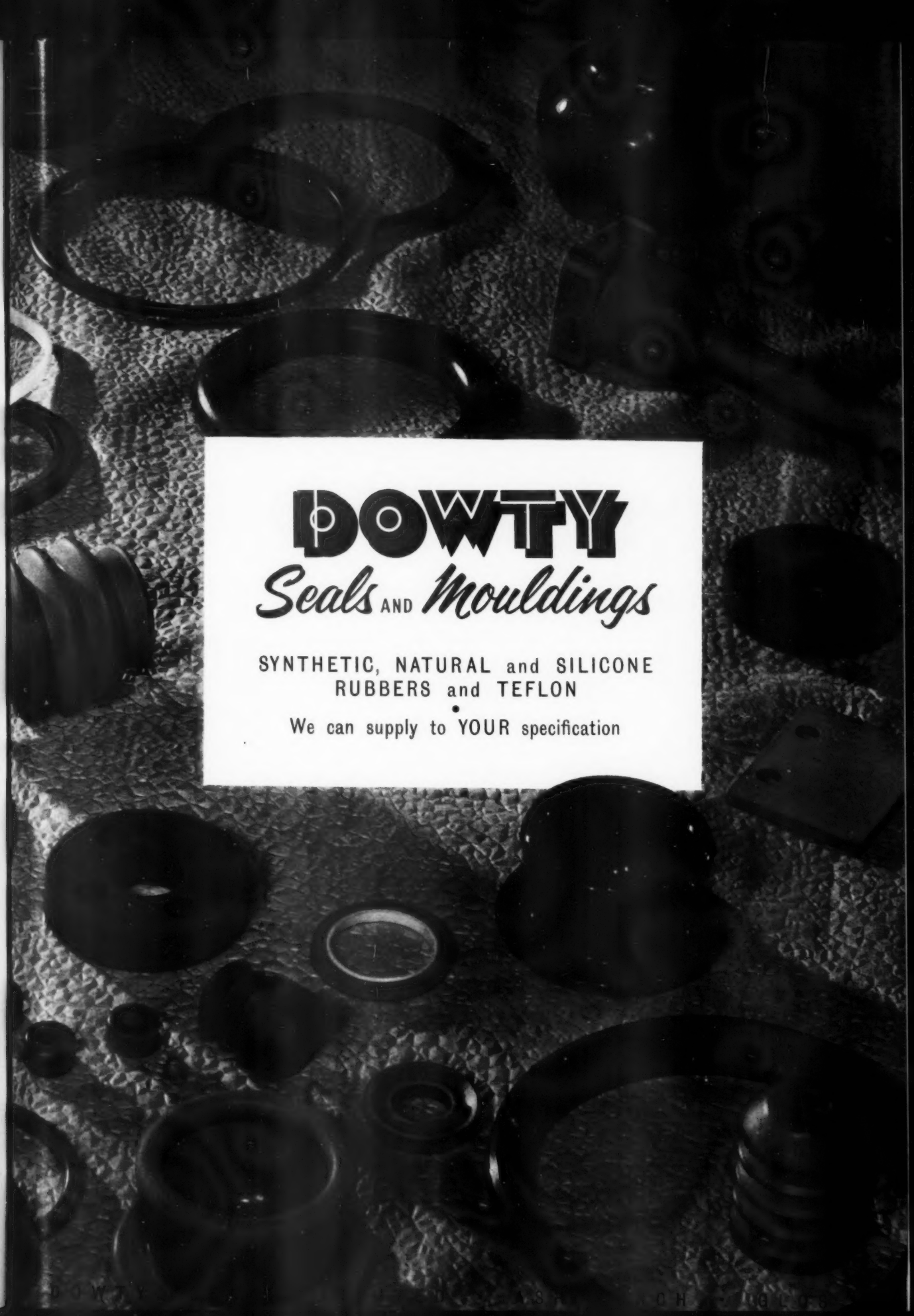
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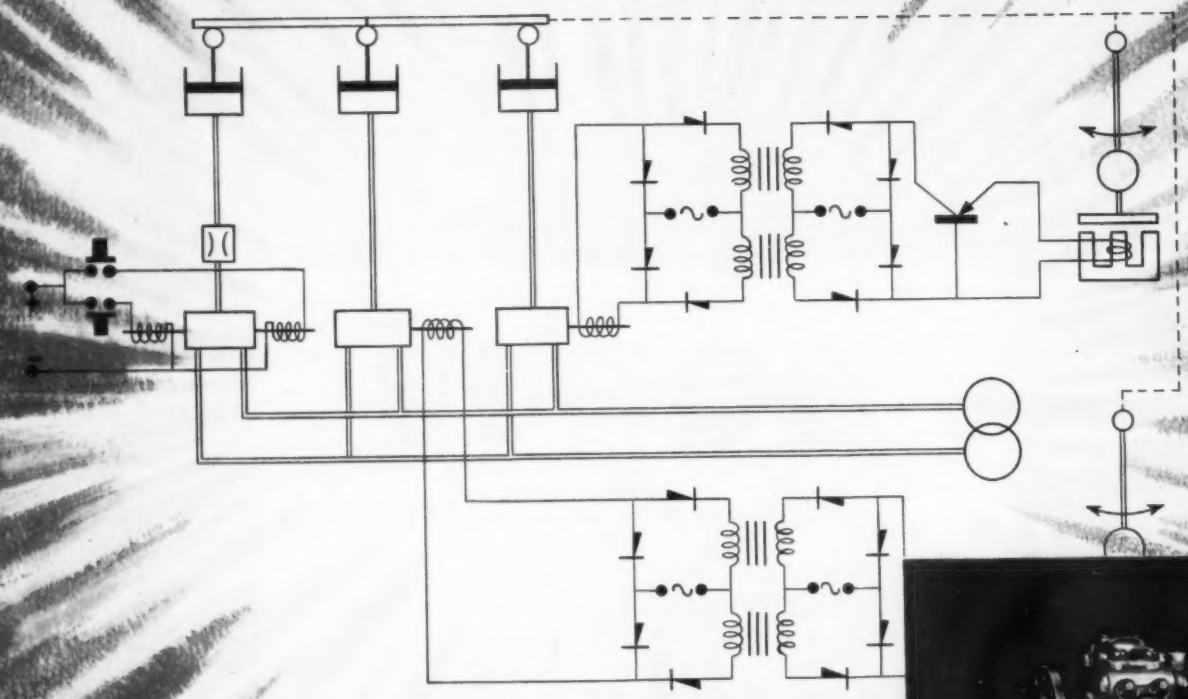
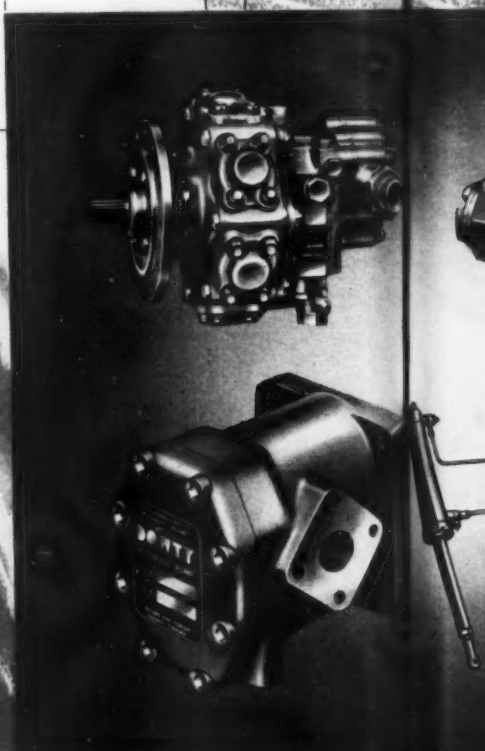
Seals AND Mouldings
SYNTHETIC, NATURAL and SILICONE
RUBBERS and TEFLON
We can supply to YOUR specification

NUCLEAR APPLICATIO





DOWTY

Nucleonics

Piston Type
Hydraulic Pumps

Hydraulic
Gear Pumps and Motors

DOWTY NUCLEONICS LIMITED

Member of the DOWTY Group

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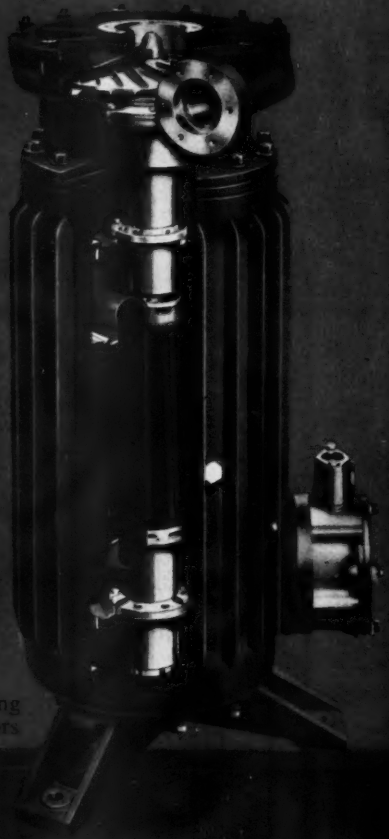
ENGINEERING

The wide resources of the Dowty Group in many specialised fields combine in a new service—application engineering for the nuclear field.

This unrivalled combination of Hydraulic, Mechanical, Electrical and Electronic engineering is strengthened by current nuclear engineering projects.



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Electric Control and Indication Units

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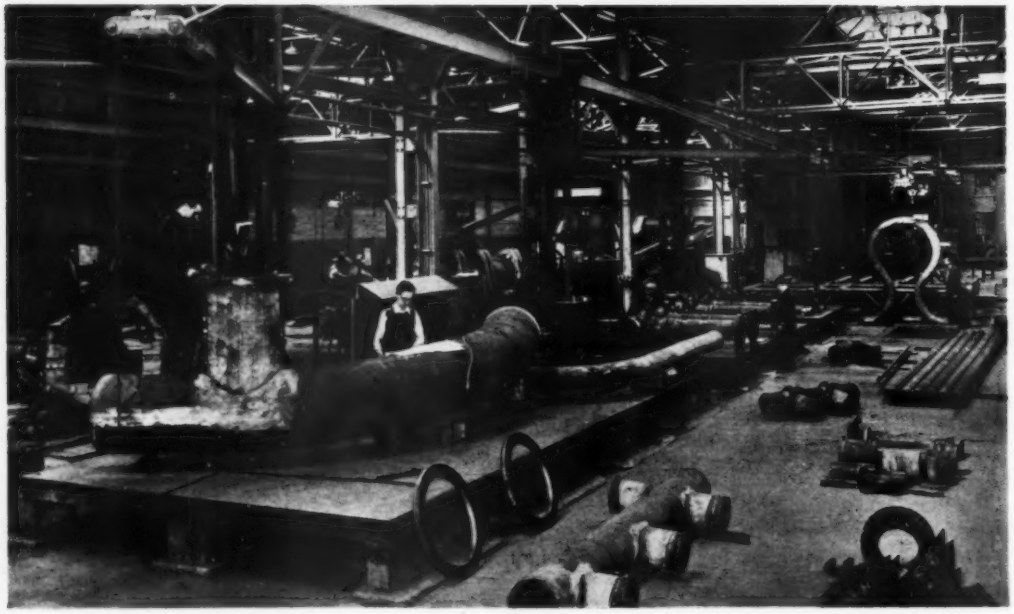
S&L

STEEL TUBES
AND MANIPULATED PIPEWORK
FOR NUCLEAR POWER STATIONS



Manipulated high pressure pipework being assembled at Stewarts and Lloyds' Tollcross works. The branch pipe on the marking-off table in the foreground is for Chapelcross nuclear power station.

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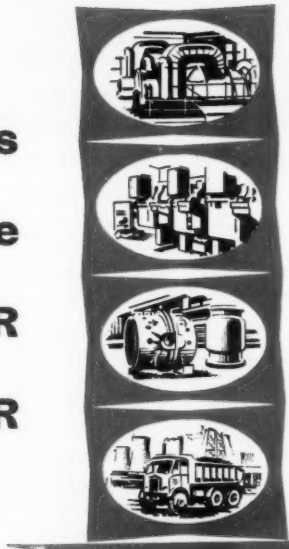

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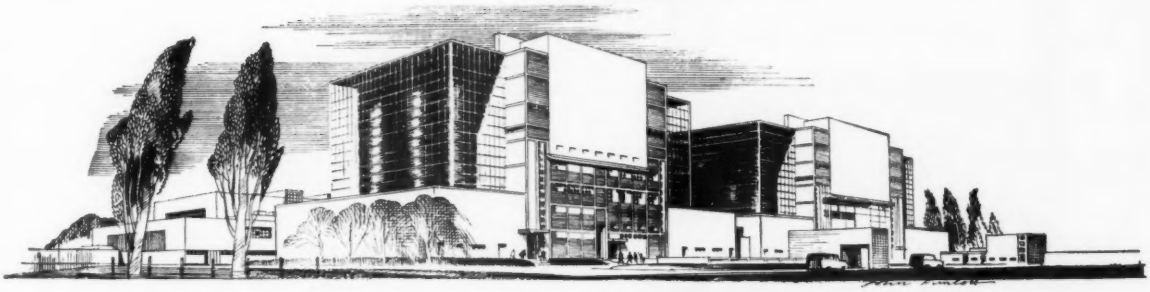

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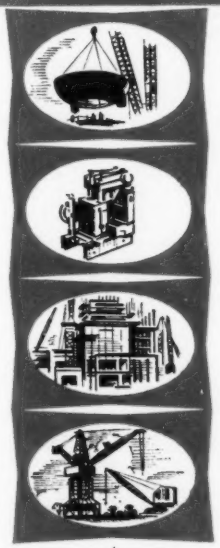

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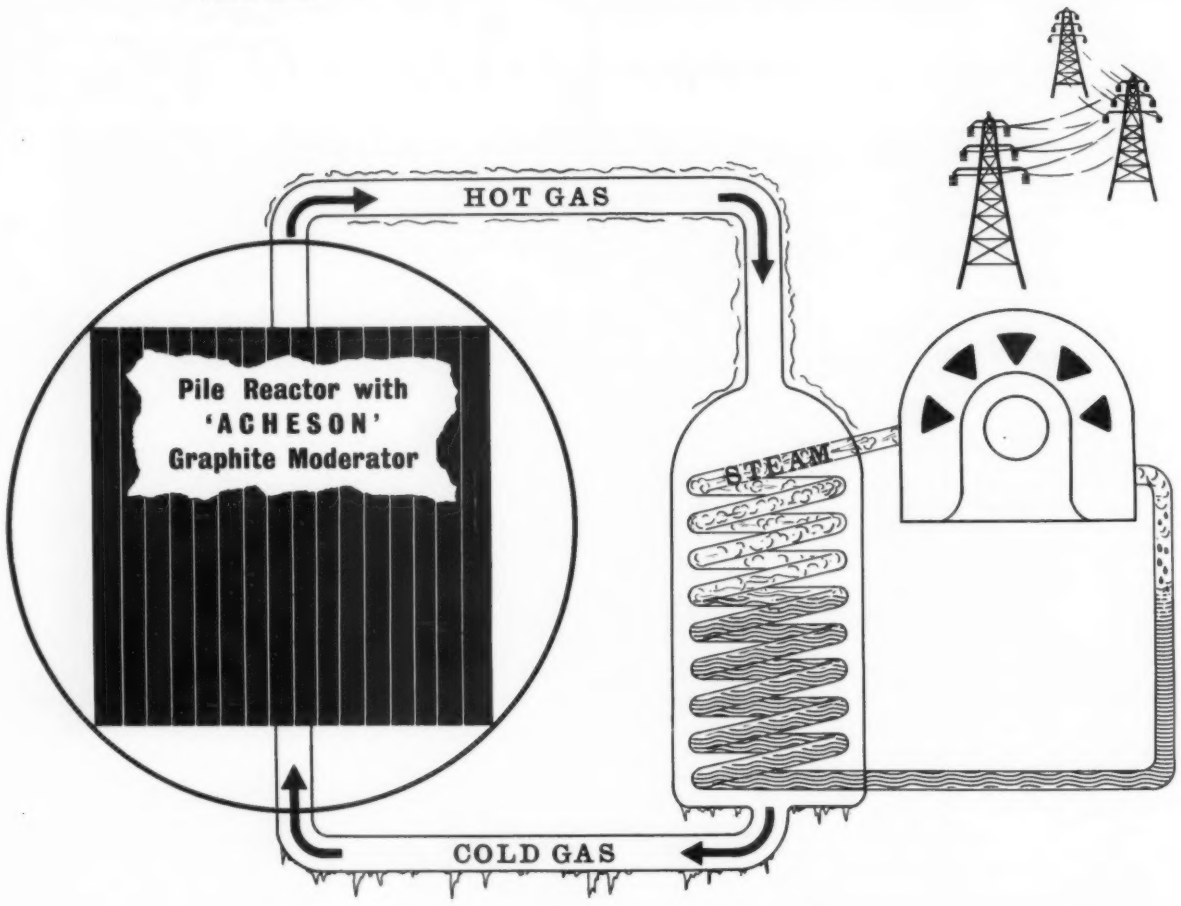

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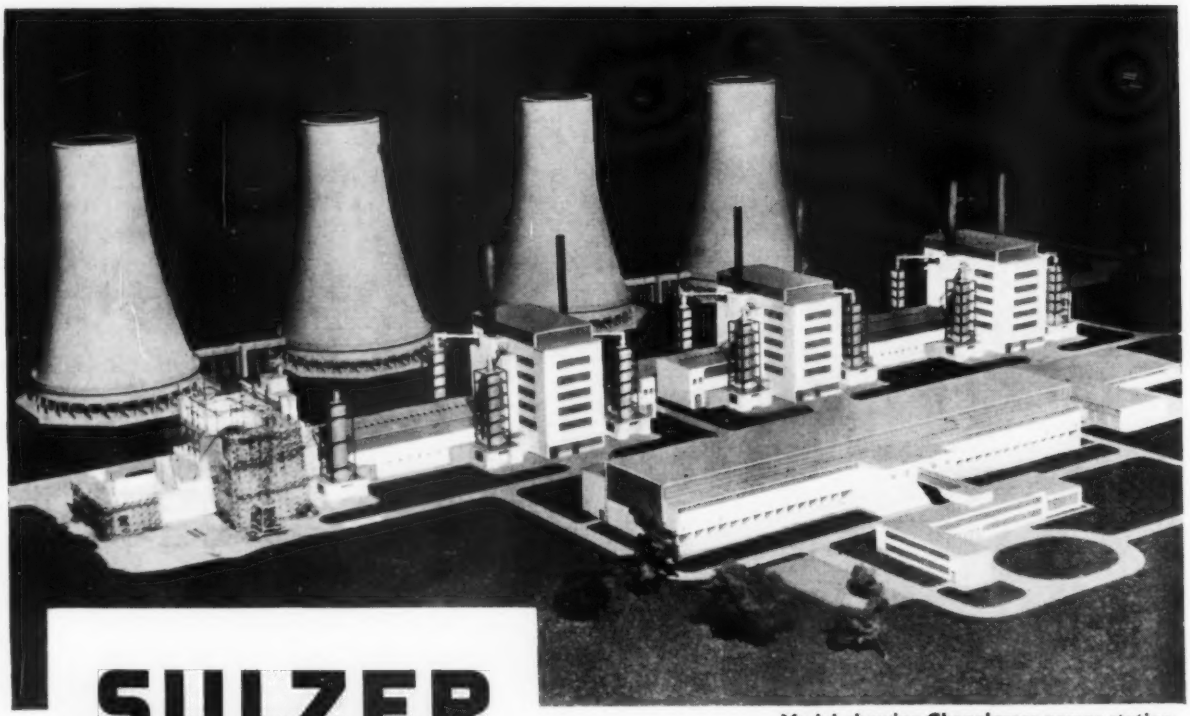

Model showing Chapelcross power station

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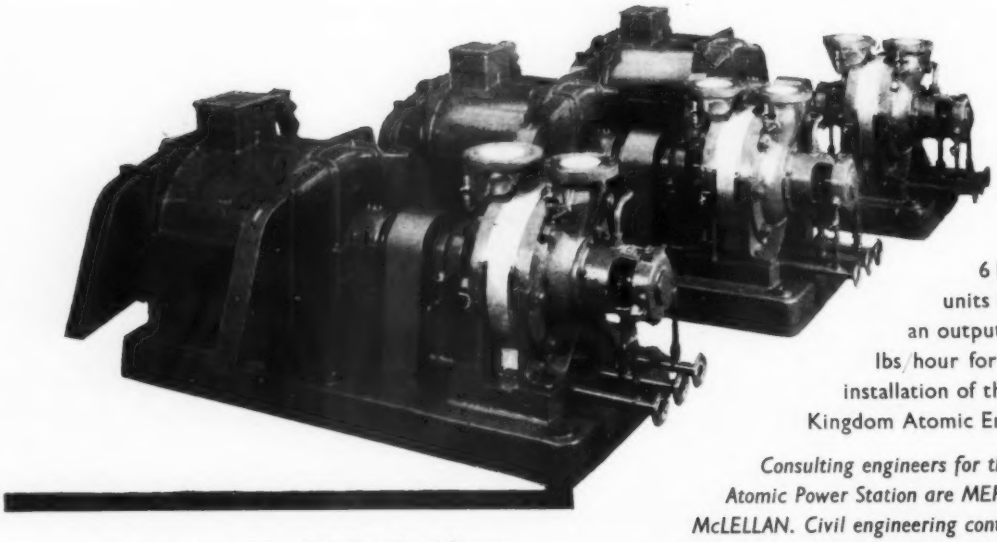

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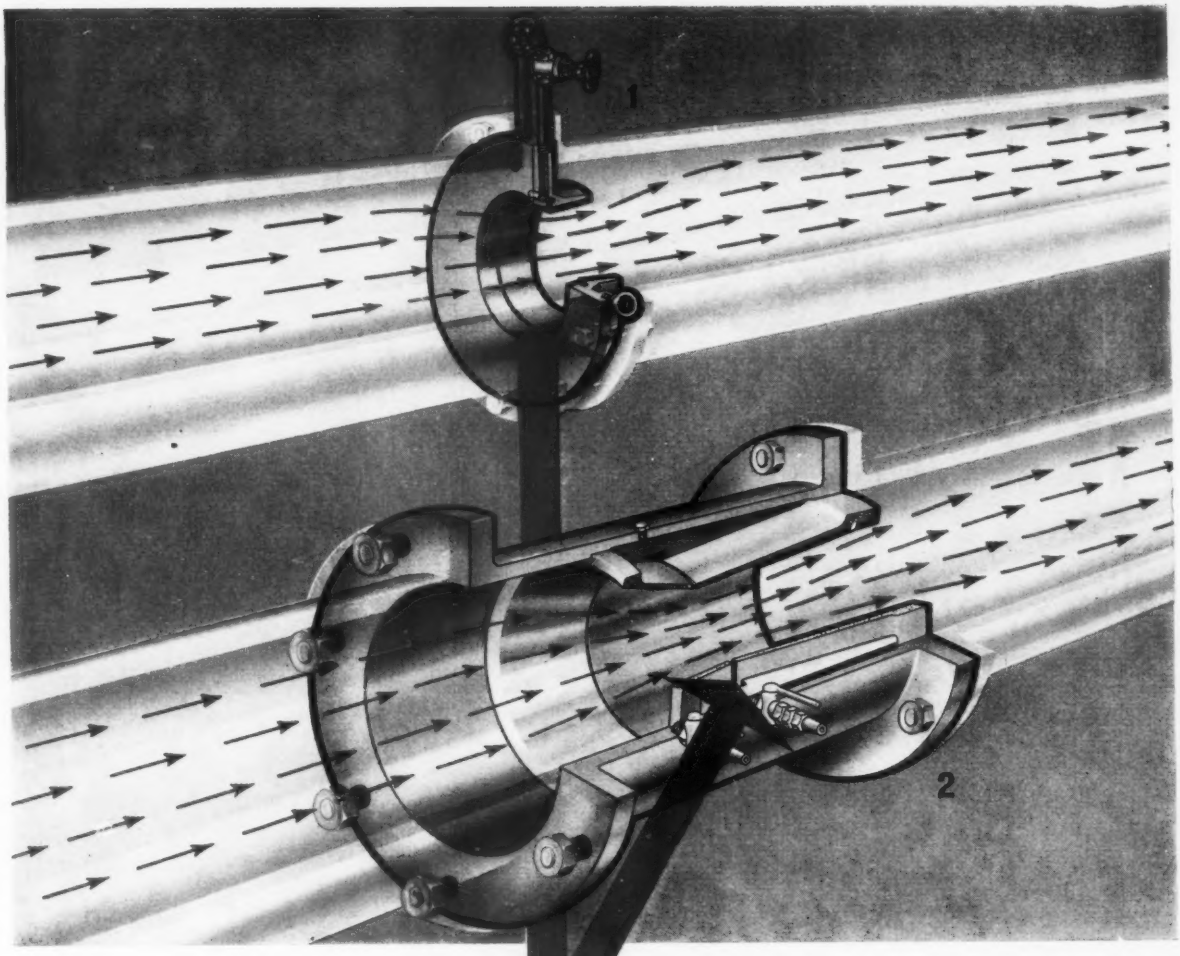

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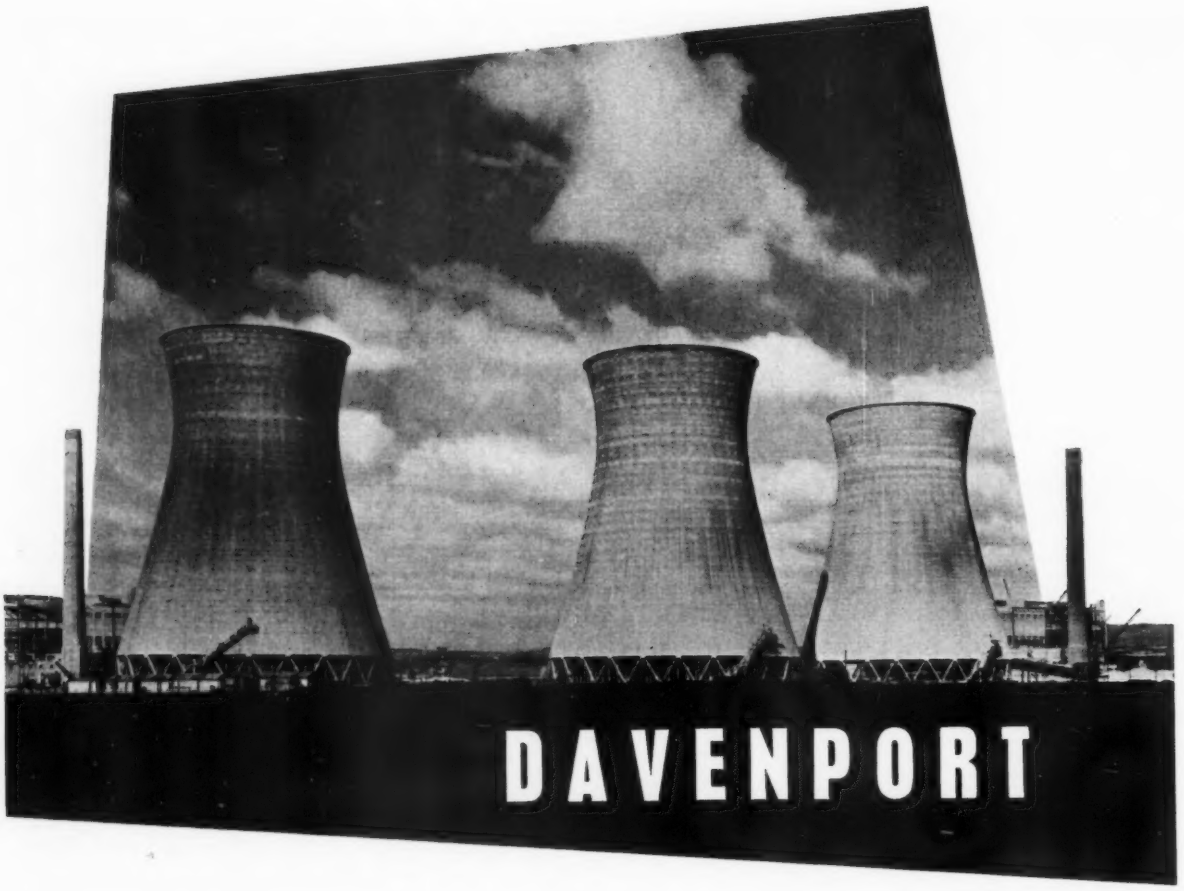

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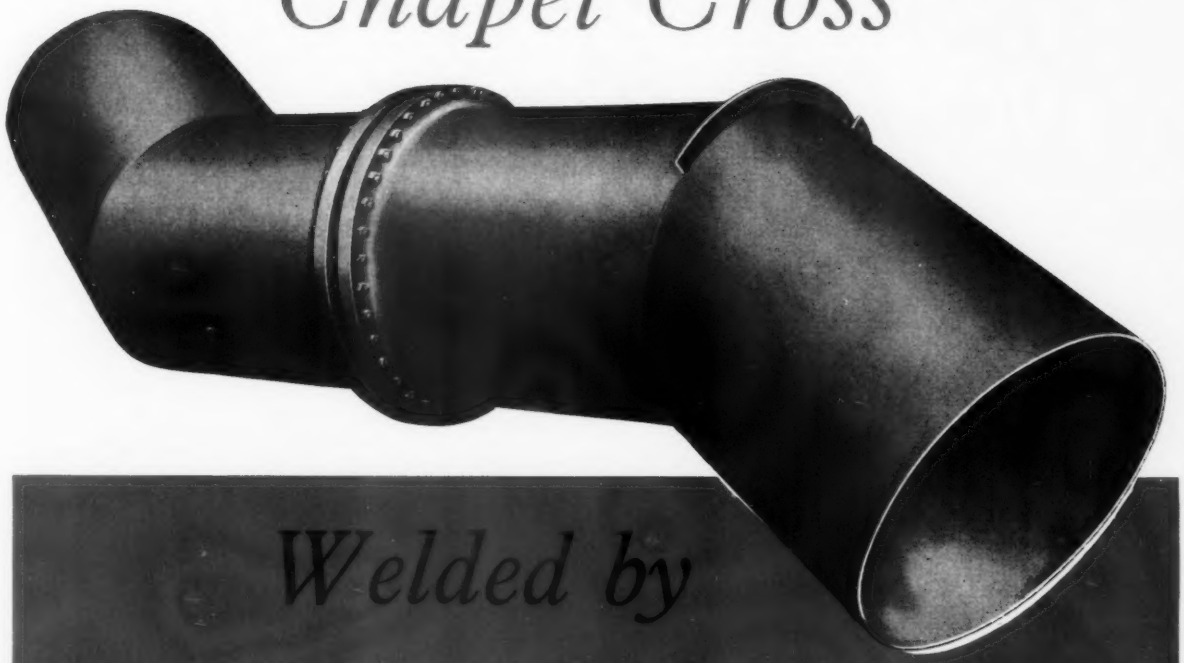

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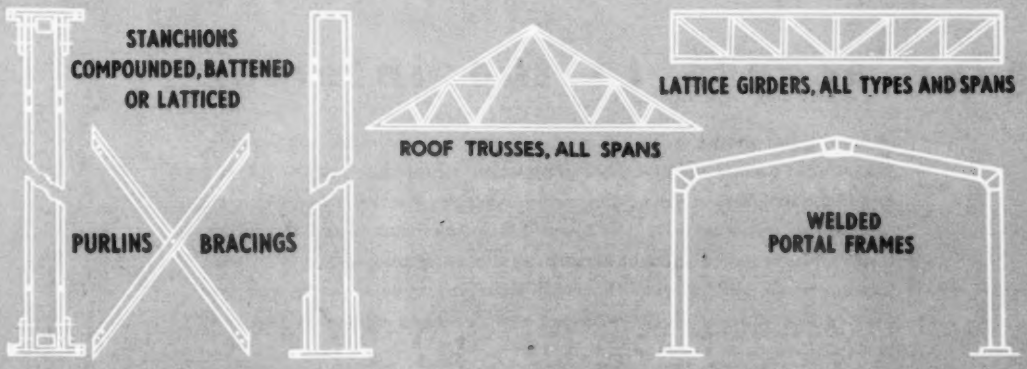

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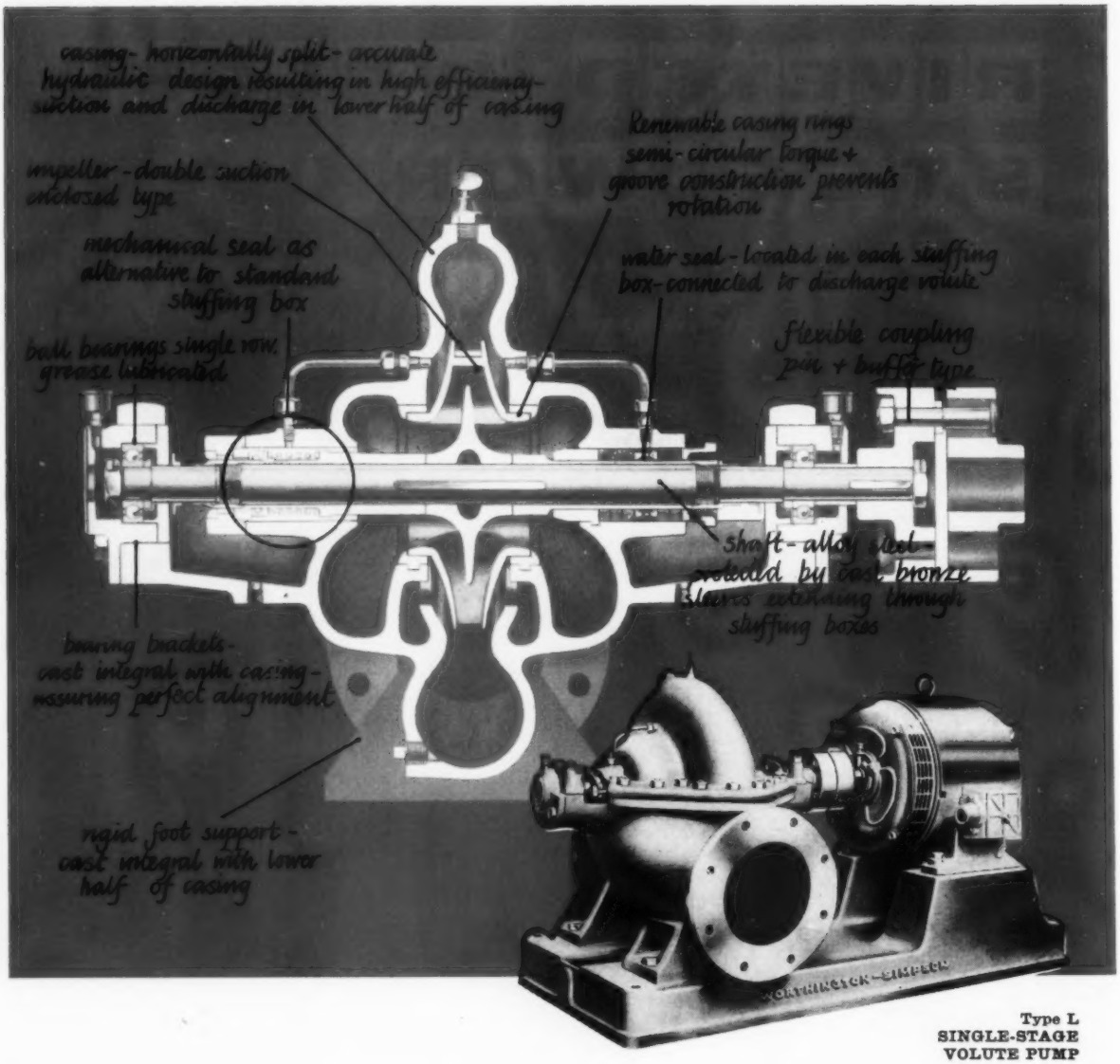
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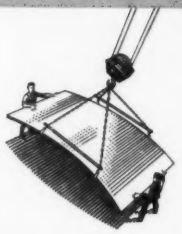

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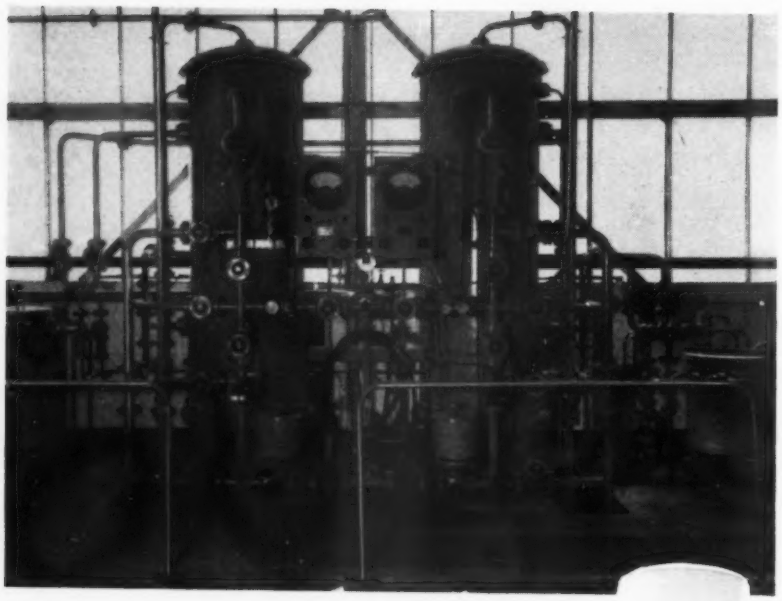

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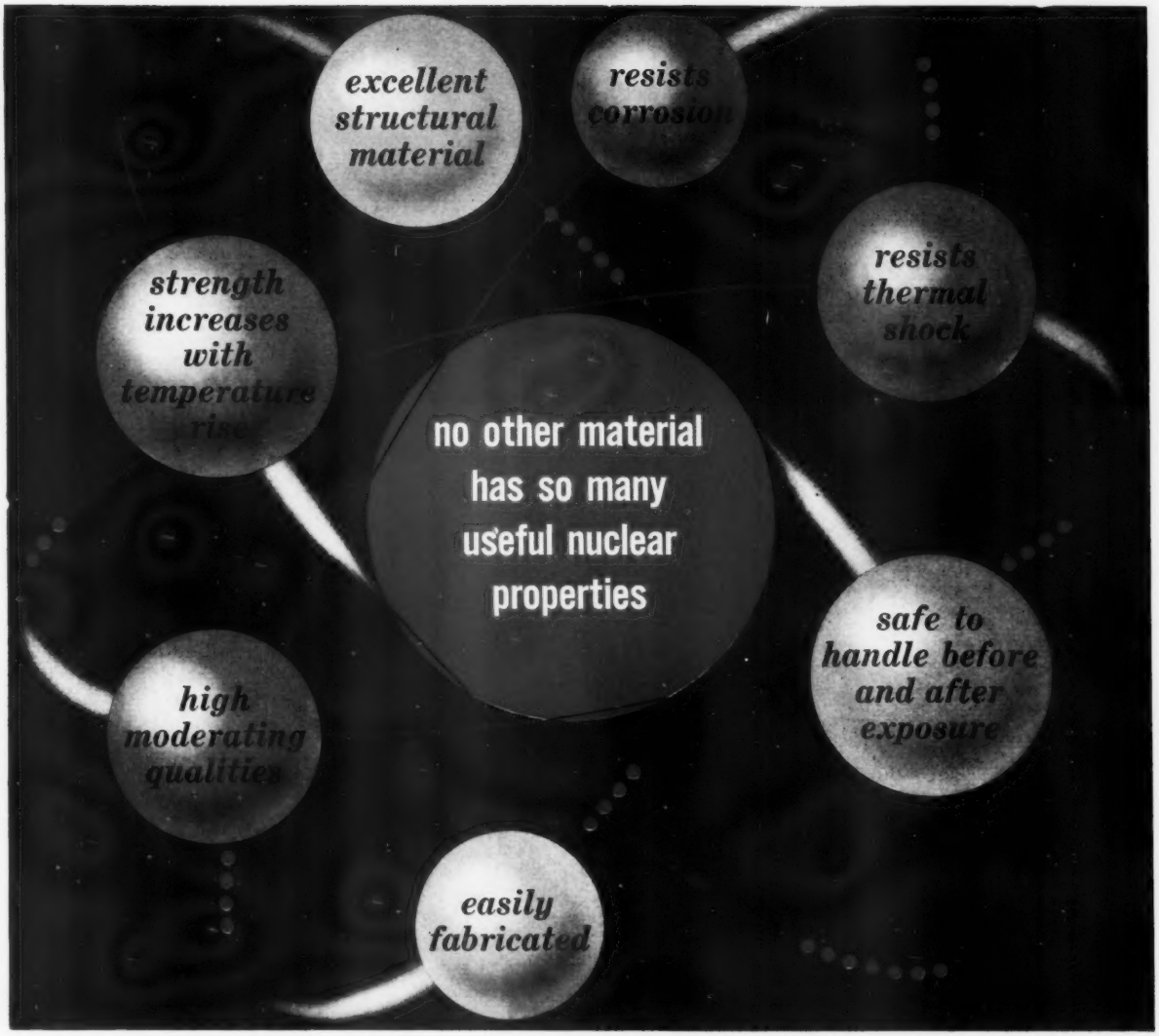
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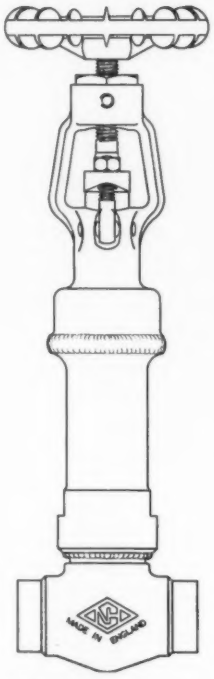

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JULY 1958 VOLUME 3 NUMBER 27

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Publishers Column

Editor's Headache

In many ways technical publishing is different from ordinary publishing and one of the most obvious differences is the question of authorship. Whereas in, say, a literary magazine the authors are professionals who make their living by writing, we are dealing with men whose main job in life is science or engineering. For them, writing is merely a sideline. In a sense they are amateurs although of course they are paid for their writing. This sometimes makes things difficult for the Editor but there is little he can do about it because practically no professional writer has enough specialized knowledge to do an article for a technical journal.

One of the biggest differences between the professional writer and the amateur is his attitude to editing. The scientist sometimes gets rather upset if his article is cut or altered in any way or if the title and captions are not exactly as he wrote them. The professional on the other hand knows the difficulties and often doesn't even bother to give his article a title, knowing full well that the Editor will probably change it anyway. We, like all magazines, also have a 'house-style' which covers preferred spellings, abbreviations etc and this is also sometimes a little worrying to authors brought up in different conventions.

'Type' say the printers, 'is not elastic' and this fact of life also leads to difficulties. If an article has been allocated say three pages and it runs to 3½, clearly something has to go if the whole magazine is not to be dislocated and deciding just what has to go is the Editor's and sub-editor's biggest headache.

Thus the production of a first-class technical magazine like NUCLEAR POWER needs both first class scientists writing for it and first class editing to make their articles easily read and assimilated. We pride ourselves that we have both.

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SIR! LETTERS TO NUCLEAR POWER

Complacency charge

SIR: In your editorial *A firm foothold* last month you seem to me to take rather a complacent view on the situation. I have just been studying the programme of the Rassegna Internazionale Nucleare which is to be held in Rome from June 16-20 and am somewhat dismayed to find that as far as reactors are concerned anyway, American speakers completely dominate the whole scene. Now this is not because we have no speakers able to talk on this subject because the four British power groups apparently found it possible to send their chief engineers half-way round the world to Australia at the beginning of June to lecture on power reactors. If it is the object of the power consortia to sell reactors abroad I should have thought Rome would have made a better platform than Sydney. Actually there is no reason why they couldn't have done both, for I see one American speaker from the Argonne National Laboratory managed to work in both meetings. Thus I'm not entirely convinced that Britain is doing all she could to sell abroad. Which is a pity since I think we have the better article.

Paris, France L. W. WILLIAMS

From recession to delusion ?

SIR: I have noticed in reading your journal that an increasing number of aircraft firms are entering the new field of atomic energy, presumably because their old activities are becoming rather restricted. I wonder however if some of these companies are not deluding themselves since it seems to me that their opportunities are not great.

Twickenham, Middlesex R. H. TURNER

▶ *It is quite true that most of the main aircraft contractors are now involved in some way in nuclear energy and that many of the smaller specialist subcontractors are finding useful outlets. In our view there is still plenty of scope and many of these firms are ideally suited to this work. The atomic industry is still in a formative state and a considerable amount of prototype and experimental work will be required for years to come, together with relatively small runs of prototype and experimental work. Its very high class of skilled worker and established tradition of refined design and precision manufacture has plenty to offer the nuclear plant designer.* *Ed*

Nuclear courses in England

SIR: Can you inform me what facilities there are in England for education in nuclear engineering at post-graduate level.

Padua, Italy G. CASTELLANI

▶ *The main centre for this is the Harwell Reactor School. The full course lasts 14 weeks but there is also a shorter course of 6 weeks. After attending this, students can go on to the Calder Operation School for 6 weeks. But places are very limited and students have to be officially sponsored by their Government or Atomic Energy Agency.*

Full-time one-year post-graduate courses are offered by Birmingham University and London University

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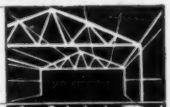

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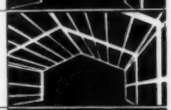

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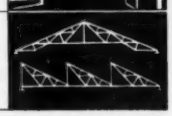

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first 500,000 kW atomic power station

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Operations on site and at the works of the Group companies, are making rapid progress. Already the shape of this great new station is revealed by a complex of approach roads, vast excavations and massive foundations. Soon the new harbour being built will be handling the full flow of plant and equipment from the Group factories, for the biggest constructional task of this atomic age.

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SIR!

(Imperial College and Queen Mary College). A number of shorter full- and part-time courses are available at several other universities and technical colleges. In addition, many of these institutions run courses in related subjects such as isotopes, radiochemistry, nuclear physics etc. You will be able to obtain full details of these from the British Council in Rome. *Ed.*

Electron beam welding in UK ?

SIR: I was most interested in the article on electronic beam welding by J.-A. Stohr in your June issue. It looks as if France has an important new development and I am aware of nothing comparable elsewhere. Do you know of any British developments in this line?

Wolverhampton, Staffs P. J. KELL

▶ Industrial Newsdesk *reports this month that one British company is to exploit the French process. Ed.*

Mercury jet switches

SIR: In the April number of NUCLEAR POWER in the article *Physical Instrumentation of a Nuclear Power Station* Mr K. R. Sandiford mentions on page 154 the use of mercury jet-type switches and mercury-wetted relays for thermocouple scanning in order to avoid spurious contact potentials in the scanning system. We would be most obliged if you could inform us what firms manufacture these.

Frankfurt/Main, Germany HARTMANN & BRAUN AG

Nuclear electronics conference

SIR: On page 259 of the June NUCLEAR POWER you mention a symposium on electronics in nuclear energy to be held in Paris in September. Could you give me more details?

Reading, Berks A. MCKENZIE

▶ *The conference will be held at Unesco House, 2 Place de Fontenoy, Paris 7e, from 16th to 20th September. The outline programme is as follows: Scintillation-and ionization-type radiation and particle detection, Pulse techniques, Reactor control and simulation, Health and survey instrumentation, Data processing, Transistorization, Equipment and components standardization. Ten half-day sessions will be held, including a visit to Saclay on Sept 20th. Application forms can be obtained from: Colloque 'Electronique Nucléaire,' Société des Radioélectriciens, 10 Avenue Pierre Larousse, Malakoff (Seine), France. Incidentally, it should be noticed that the symposium follows directly on the Geneva conference.* *Ed*

More metallurgy please

SIR: I find the NUCLEAR POWER YEAR BOOK a most useful reference to have on my desk but I am a little disappointed to find very little on metallurgical topics.

Cleckheaton, Yorks. J. P. WRIGHT

▶ *The latest edition of the Year Book—due out very soon—contains a greatly expanded section on metals and should meet your requirements.* *Ed.*

As the reactor temperature rises . . .

The attainment of higher operating temperatures in the reactor is dependent on far reaching problems which may take some years to overcome.

One of the outcomes of this technical development will be the need for ever higher standards of thermal insulation to counteract the increase in fuel consumed in producing this valuable high temperature heat.

The insulating materials required for this application will have to combine structural strength and durability with superlative insulating properties and the ability to withstand high temperatures without shrinkage or distortion, in fact, just the properties offered by the Fosalsil range of insulating bricks, concretes and lightweight slabs, which are currently in wide use for lining power station boilers.

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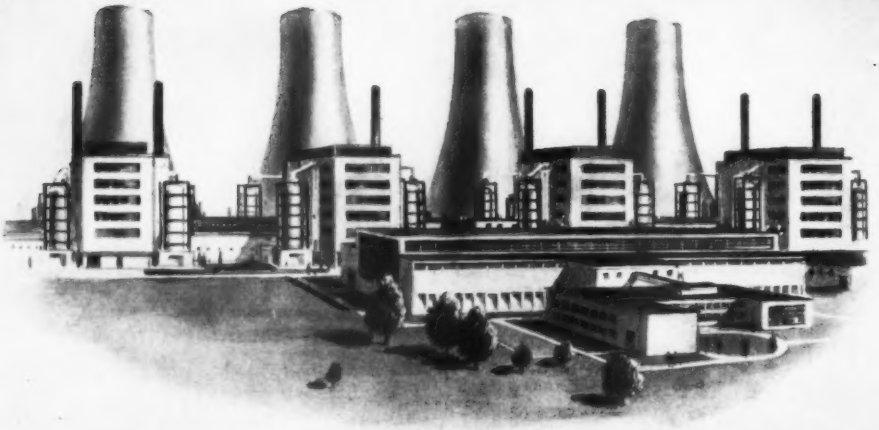
CHAPELCROSS

ATOMIC POWER STATION
TO BE LUBRICATED BY
WAKEFIELD - DICK



The U.K. Atomic Energy Authority leads the world in the industrial application of atomic energy. To lubricate their new Atomic Power Station at Chapelcross they have chosen the lubrication specialists—Wakefield-Dick.

Wakefield-Dick have also been commissioned by the C.E.G.B. to supply lubricants to the Berkeley Nuclear Power Station.

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Nuclear Power
THE JOURNAL OF BRITISH NUCLEAR ENGINEERING
JULY 1958 VOLUME 3 NUMBER 27

Setback

THE NEWS that Hinkley Point and the future British nuclear power stations are to be modified in design so that they will produce weapon-grade plutonium is the hardest blow yet struck at the nation's power programme and must have the effect of putting back the clock several years. The decision is of course a political one upon which it would not be proper for us to comment. But it should be noticed in passing that the plan is not conditional—the stations are not simply to be adapted so that they can produce explosive if necessary : necessity only arises in the end use of the product, which is apparently to be stockpiled from the start.

Just what the change in policy means in technical terms is not easy to assess without access to the classified information relating to plutonium production but it is clear that when plutonium-239 is the main product, the oft-quoted mystic figure of 3000 megawatt-days per ton burnup—upon which all power reactor economics are based—ceases to make any sense. Maximum production of weapon-grade plutonium—that is Pu-239 with a certain maximum, but classified, amount of non-fissionable Pu-240—can be expected in fuel having an irradiation time of something less than 1000 megawatt-days per ton, thus the first thing that will happen is that arrangements will have to be made for changing the fuel perhaps as much as four times as frequently as would be the case if power were the only consideration. This will mean much more elaborate and extensive fuel-handling and cooling arrangements, and, of course, more fuel in the pipeline. It was stated by the Ministry of Defence that Hunterston is already suitable for this new requirement and it is interesting to note that the fuelling arrangements here do seem rather more elaborate than those at Berkeley and Bradwell, which escape the new policy.

Curiously enough, on the very day the Ministry of Defence statement was issued, Sir Christopher Hinton was telling delegates to the British Electrical Power Convention at Brighton that the 'vital problem' which had to be tackled in order to bring down power costs was the development of better and more efficient fuel elements. Now that only very moderate burnups are required the physicists and metallurgists will be relieved of some very knotty problems, not least of which is the intractable question of fuel swelling in uranium slugs of the kind used in these reactors.

Another effect of the new policy is that information is likely to become even more restricted. With the electricity authorities' reactors we have been assured that no question of national security would arise—although the commercial security was bad enough. Now we will have both.

The question remains, what price is the Government prepared to pay for this plutonium? In case of war it would of course be priceless but one lives in hope that it will end up only as reactor fuel. Certainly the price to be paid must at the very least represent the loss to the electricity authorities resulting from the very low fuel burnup. But even if the economics are 'cooked' by some such device as this, the new development can only retard future technical progress of the graphite-moderated, gas-cooled reactor.

Tick **No 93** on reply card for further details

Power to foster new industry

In many corners of the world, the bare essentials of primitive living are still laboriously made by hand. Industry could bring new hope to such places; lack of it brings only bitterness and distrust. Their first need is for power, plentiful and cheap.

Nuclear energy promises such power, and in Britain that promise is fast becoming a fact.

At Berkeley, one of the first of our nuclear power stations is making rapid progress. The AEI-John Thompson Company has harnessed the skills of such mighty firms as John Thompson, BTH and Metropolitan-Vickers to the task. Today, this consortium of talents is at the service of the world.

A·E·I

JOHN THOMPSON

Worldview

the month in atomic energy

Power plants to make bomb Pu

The nuclear power programme is no longer to be independent of the military one. Some reactor designs will be modified to allow for the manufacture of weapon grade plutonium as a contribution to defence and a start has already been made on adapting the design of the fuel charging and discharging apparatus for the reactor under construction at Hinkley Point, so that the fuel can be removed before the plutonium produced changes from Pu 239 to Pu 240. Hunterston is also to be used for the purpose, though no design change is necessary in this case, but the stations at Berkeley and Bradwell are unsuitable and have progressed too far for any alteration to be made; these will remain as the only two entirely civil nuclear power stations in the country. The proposed stations at Trawsfynydd and Dungeness will be designed specifically to meet the new requirements.

The Ministry of Defence, revealing the change in policy, said on June 17 that the step was being taken as an 'insurance' against future defence needs. The modifications would not delay the construction of the reactors involved nor would it affect their 'normal 'efficient operation as civil power stations.' When asked whether the rest of the stations to meet the target of 5000-6000 MW by 1966 would be affected the Ministry spokesman said it was 'impossible to say at this stage.' He added that the suitability of Hunterston for the new purpose was 'entirely fortuitous' and had not been premeditated. The cost of the modifications to the other stations would be borne by the Ministry but was a 'very small proportion' of the total cost of the stations. They would pay for the fuel elements containing weapon grade plutonium but no figure could be quoted. However, an authoritative source puts the price at 'not less than £5000 per ton.'

Atomic pact signed with Japan

The ten-year agreement which will enable Japan to buy power and research reactors from the UK, together with the necessary fuel, was signed in London on June 16. This opens the way for the purchase of a 150 MW power station from one of the consortia who are tendering by July 31. On the same day Japanese representatives in Washington signed a similar pact with the US government, but in this case the total amount of uranium 235 which Japan could buy from America in the next ten years is limited to 2700 kg.

The British agreement covers the possibility of help for Japan to build plants for the manufacture of fuel elements and processing used fuel, the provision of training facilities for Japanese engineers in the UK, and the exchange of unclassified technical information.

In view of the protracted discussions on the point, the agreement on responsibility for any accidents is interesting. The UK Atomic Energy Authority will do its best to ensure that material and equipment supplied by them is free from defects but will be protected from third party claims if damage occurs after delivery, 'attributable to the production and fabrication of the fuel.' Plutonium and other fissionable materials recovered from reactors will be at the disposal of the Japanese Government but until required must be held in stores chosen by the AEA in Britain or Japan. Any not wanted by Japan is to be first offered to the UK and if it is not needed the British government is ready to approve transfer to any countries or organizations with which it has 'peaceful use' safeguard arrangements of the same scope as those in the present agreement, which are modelled on the IAEA statute.

ZETA team to view Soviet work?

Sir John Cockcroft has provisionally accepted an invitation from the Soviet Academy of Sciences to take five or six of the ZETA team to Moscow this year to see Russian work in the same field. The offer was extended by Academician Igor Kurchatov, who visited Harwell two years ago and it has been accepted on the understanding that it would not be possible until after the Geneva conference. Sir John has suggested a date in November and is awaiting a reply.

CEGB fix site for No 5

For their fifth nuclear power station the Central Electricity Generating Board has decided on a site at Dungeness in Kent and they are to ask the Ministry of Power and the local planning authority for permission to develop it. Investigation of the site—immediately west of the lighthouse near the tip of the Dungeness promontory—has shown that it is 'admirable for nuclear power generation,' say the Board. The water is deep close to the shore so that there would be no

SITE FOR ATOMIC POWER. Consisting of shingle and flanked by a beach which shelves quickly into deep water the site beyond the Dungeness lighthouse in the centre has been chosen by the CEGB for a 500-550 MW station

difficulty in providing the large quantities necessary for cooling. Trial bores have been made and the Board is satisfied that the foundations would be capable of supporting heavy reactors.

The station may be the largest so far, with an output of 500-550 MW. Outputs of the three others under construction are 500 MW (Hinkley Point), and 300 MW (Berkeley and Bradwell); 500 MW is proposed for a station at Trawsfynydd in North Wales. The Dungeness plant would be connected to the 275 kV grid which is being brought to Lydd, about three miles away, to link with the French electricity system via the projected cross channel cable.

'Fuel element research vital'

Nuclear plants will be unable to continue competing with conventional plants unless major technological advances are made by 1966, warned Sir Christopher Hinton, chairman of the Central Electricity Generating Board, on June 17. Addressing the British Electrical Power Convention at Brighton he said that if the research and development work which was necessary to bring down the capital cost of nuclear power plants was not complete and sufficiently well established by 1966/67 when orders for stations to work at reduced load factors would have to be placed, then we would have to swing back to the use of conventional power plants. This would be bound to impose serious strains on the manufacturing industries, and since the nuclear programme would have diverted some of the effort the conventional plants we should have to order would be not as good as they could have been if there had been no diversion. The only alternative would be to continue to install nuclear plants even though generating costs would be higher.

'Capital costs must be brought down by improvements in all parts of the reactor,' he went on, 'but the vital problem lies in the development of the fuel elements. The programme for the construction and operation of industrial reactors must be kept reasonably in step with the research programme, because only these industrial reactors provide information on the irradiation of full-scale fuel elements on a basis which is large enough to be satisfactory: the reason why practical experience of long fuel element exposures was not available lay in the fact that all initial reactors were built primarily for the production of plutonium for defence purposes.'

How, Citrine in birthday honours

The nuclear industry comes in for its share of the honours again in the Queen's Birthday List this year. Friston Charles How, secretary of the Atomic Energy Office since 1954, is knighted, and so are Willis Jackson, director of research and education at Metropolitan-Vickers, and John Pickles, Chairman of the South of Scotland Electricity Board. Lord Citrine, who joined the UKAEA as a part-time member early in the year and was appointed part-time member of the newly formed Electricity Council, is made a GBE.

Among the CBE's are E. K. Cole, chairman and managing director of Laurence Scott and Electromotors, and T. W. F. Brown, director of Parsons and Marine Engineering Turbine Research and Development Association. Chief radiological safety officer at Harwell, W. G. Marley, is made an OBE, with R W. Reynolds-Davies, secretary of the Institute of Fuel, and H. A. Brooke, an engineer at AWRE, Aldermaston, is among the new MBE's.

Berkeley—30 months to go

Eighteen months after work began on Berkeley nuclear power station the main lines of the No 1 reactor building, nearest the Severn Estuary, are already taking shape. Inside the supporting steelwork for the first heat exchanger one of its steam drums waits to be hoisted into position

DMTR goes critical

The 10 MW materials testing reactor at Dounreay, a duplicate of PLUTO at Harwell, is now in operation. On May 24, Dr Robert Hurst, director of the Research Establishment, guided into position a rod containing enriched uranium fuel, which made the reactor go critical. Initial work will be on testing uranium and other metals which will be used in the fast breeder reactor. Tests will be continued over the next three months at very low power, and then at increasing load to secure data on performance at each stage.

The DFR was originally scheduled to go into operation last spring, but the Atomic Energy Authority seem to be having a rethink on some of the design aspects and it is not likely now to go critical before the end of the year. Sir William Cook, speaking at the opening of the UKAEA display at the recent Hanover fair, gave early next year as a possible starting time.

UK moves closer to Euratom

The Government has appointed a representative to Euratom, and has agreed to early talks with a view to negotiating a technical collaboration agreement. The representative is Sir William Meiklereid, who is already Head of the UK Delegation to the High Authority of the European Coal and Steel Community, with Ambassadorial rank. Welcoming the news recently, the Euratom Commission expressed its belief that the appointment would contribute to the establishment of 'close relations' with the UK. 'In this way,' the statement continued, 'a few months after the entry into force of the Treaty, The Euratom Commission will have official relations with the two principal nuclear powers in the free world with which it hopes to establish fruitful collaboration.'

The US has already recognized Euratom at Ambassadorial level, and a joint working party has agreed on a plan for US technical and financial assistance on the installation of 1000 MW of nuclear

power plant from American specifications (*Worldview* April). The agreement has been approved by Euratom and is now being considered in Washington. The new move on Britain's part follows several exhortations to the Government by members of Parliament to take account of the urgent need for a stronger association with Euratom, including a joint working party.

Sir William Meiklereid was commercial minister at the British Embassy in Paris before his appointment to the ECSC in August 1955. His long career in the Consular service has included work in Siam, Holland, the East Indies, and French Indo China.

Give and take in Washington

Britain has agreed to provide the US with detailed information about the uranium fuel elements developed for Calder Hall, Atomic Energy Commission officials said in Washington on June 11. A spokesman disclosed that the agreement was reached during discussions between Sir Edwin Plowden, chairman of the UK Atomic Energy Authority, and officials of the USAEC on closer cooperation in the atomic energy field. There has been some difference of interpretation (*Worldview*, June) on the scope of the agreement reached a year ago under which Britain offered to supply information on the design of Calder Hall, but as a result of the Washington talks 'misunderstandings have been resolved.' No official statement has yet been made by the Prime Minister or the UKAEA on these talks.

The possibility of the *Dreadnought* submarine being powered by a US Westinghouse reactor became a little more definite with a statement by Rear Admiral Rickover, head of the US Navy's nuclear submarine programme, that the British Admiralty has tentatively agreed to a purchase. Speaking at a session of the Joint Congressional Atomic Energy Committee he said the deal would involve about £M9 and would be made through a commercial contract with a British firm. Neither government would be directly involved in the sale. The Bill which would authorize such transactions has been passed by Congress and is now to go before the senate.

Owen gets second deputy

The second of the deputy managing directors to the Industrial Group of the AEA recommended by the Fleck report has now been appointed. He is P. T. Fletcher, who moves from his job as Director of Engineering. This is taken over by H. V. Disney, formerly deputy director of Defence Plants, Supplies and Services.

Mr. R. V. Moore, deputy director, civil reactors, has been promoted to Director of Reactor Design. He was one of the first engineers to join Harwell, where he worked from 1946 to 1953, and was Group Leader for the construction of BEPO. His considerable contribution to the development of Calder Hall included the job of group leader for design studies of PIPPA, and after joining Risley as assistant chief engineer in 1953, he became the first chief engineer for Calder.

After moving to the AEA from the Ministry of Works in 1954, Paul Fletcher has moved up rapidly in the Industrial Group from Deputy Director of Engineering to his new job directly under Sir Leonard Owen. The new Director of Engineering, H. V. Disney, was a member of the original team which started the Department of Atomic Energy at Risley in February 1946.

No atomic power yet for NE Scots

The atomic power station proposed for the North East of Scotland is unlikely to materialize for about ten years. The Ministry of Labour, replying to an approach by the Aberdeen local employment committee regarding the location of new industries, said recently that though an atomic energy station was visualized for the North East it was a long term project and no development was likely before 1968. Eventual construction was doubtful and dependent very largely on the overall demand for electricity in Scotland at the end of 1966.

AUSTRIA

First reactor to be American

In spite of competition by British firms the main instrument of a nuclear research centre near Vienna is to be a 5 MW American Machine and Foundry company swimming pool reactor. In awarding the contract to AMF recently Dr Higatsberger, technical managing director of the Austrian Study Group for Atomic Energy, the joint government and industrial organization which will own and operate the centre said, 'after careful evaluation of many proposals received from American and British firms AMF was selected primarily because of special technical features offered by their design and the extensive experience of AMF in building such reactors for other countries throughout the world.'

CANADA

NRU shut down after accident

The NRU reactor at Chalk River has been shut down following an accident in which radioactive dust was spread throughout the interior of its twelve storey building. No one was hurt, said Atomic Energy of Canada Ltd, announcing the accident, but the reactor is likely to remain shut down for several weeks while the whole of the building is examined and decontaminated.

The trouble started when the reactor had been shut down to remove a defective fuel rod. 'This operation proved difficult,' said AEC, 'and part of the rod broke off and caught fire.' It was promptly extinguished, but not quickly enough to prevent widespread scattering of radioactive dust. The area surrounding the building was not contaminated, and other work at the establishment is now proceeding normally. NRU, a 200 MW natural uranium-heavy water reactor, was built at a cost of about £M19 and is the only one of its kind in existence.

IRELAND

Reactor for Dublin?

After studying the problem for two years the Atomic Energy Committee has decided that Ireland should have a research reactor and has narrowed the choice to a swimming pool type of either American or British manufacture. In its report, now completed, the Committee says that the reactor should be operated —at least for the first five years—by a university institution under the overall direction of a permanent Atomic Energy Board set up to promote a programme of training and research. The best site for the reactor would be Dublin, in an area 'free from continuously occupied buildings for a radius of 500 ft.' Estimated cost of the 1 MW American type would be £330,000, with running expenses of £17,000 a year excluding fuel costs of £5000 a year. The British reactor would cost £620,000 with total operating costs of £37,000 a year including £9,000 for fuel. It differs from the American type, says the report, in that it requires a smaller tank and building. The capacity of the reactor—which sounds rather like an Associated Electrical Industries type—is given as 1 MW capable of being raised to 5 MW for short periods.

POLAND

First reactor in operation

Constructed with the help of equipment and information provided by the USSR, Poland's first reactor, EWA, began operating on May 31 at the central nuclear research establishment at Swierk, near Warsaw. It is light water moderated and cooled, using 10 pc enriched uranium fuel, and power rating is 2 MW. In the course of the year the Department of Nuclear Engineering will start experimental work linked with the projected construction of a second research reactor. This will be entirely Polish built

and is intended to act as a prototype for the first nuclear power station, which is scheduled for completion about 1965. The station will use natural uranium fuel, graphite moderator and gas cooling, and capacities spoken of are either 50 or 200 MW.

EWA is designed to run for 600 days without change of fuel. The elements are located in 51 sections of aluminium structure each having 16 channels and the total weight of uranium-235 involved is 6·5 kg. Surrounding the fuel section is distilled water to act as moderator, cooling agent and shield. Mean temperature of the water in the active zone is 35°C and the uranium rods run at a maximum temperature of 90°C.

The water from the reactor container is pumped round a closed circuit at the rate of 900 cu m/h to the two heat exchangers, which transfer the heat through

POLAND'S FIRST This 2 MW light water moderated and cooled reactor, built with Russian help, is now in operation near Warsaw

a surface of 95 sq m to ordinary water flowing at 250 cu m/h in a second closed circuit including a basin outside the reactor building. In the first circuit 150 cu m/h of the distillate is pumped through a gas extractor to remove the fulminating mixture produced during work in the reactor. At the same time 10 cu m/h is directed through filters in the form of an ionic exchanger which is intended to eliminate any impurities arising from corrosion of the pipes.

Research and experimental facilities consist of nine 60-100 mm dia horizontal, and ten 40-45 mm dia vertical channels, three special channels for biological work, one graphite column for investigation of thermal neutrons and four hot cells equipped with remote control manipulators. Three safety regulators are held over the active zone by electromagnets. If a danger signal should be given the current through them could be cut out and the reactor shut down in half a second.

SPAIN

First steps in 220 MW project

A design study for a 220-250 MW nuclear power plant to be located in Northern Spain, probably at Sobron on the River Ebro, is under way by the US Internuclear Company. The contract was awarded by Nucleàres del Norte, SA, Nuclenor, a group of utility companies, and Dr Marvin Fox, vice president of Internuclear company, has visited Spain to supervise the selection of a site.

Internuclear has held an advisory contract since last year with the Italian Società Elettronucleare Nazionale (SENN) and assisted in the development of the ENSI—Energia Nucleare Sud Italia—project for a 150 MW station at Garigliano, tenders for which were submitted last April (*Worldview*, May).

UNITED STATES

Strauss goes; new man named

The atomic energy programme will no longer be directed by Lewis L. Strauss. He decided to retire as AEC chairman at the end of his present five-year term on June 30, and his place on the five-member commission will be taken by John A. McCone, a Los Angeles businessman, who has not previously been associated with atomic energy development. Strauss will remain in the administration in the new post of special assistant to President Eisenhower in the Atoms for Peace programme. The White House, in announcing the changes, said it was not known whether the President intended to designate McCone as the new chairman, but in any case no action would be taken until the Senate had confirmed his appointment to the Commission.

Mr Strauss has been the centre of considerable political strife, and his mention in a letter to the President refusing reappointment, of 'circumstances beyond the control of either of us' which 'make a change in the chairmanship of the commission desirable,' may well have referred to his running political feud with some Democrats on the Joint Congressional Committee on Atomic Energy.

It is reported that some of the trouble has arisen from his preference for encouraging industry rather than the Government to take the lead in developing atomic energy, and that he believes the feud to have been largely responsible for lowered morale within the commission staff and the departure of several officials. In this connexion it is interesting to note that general manager Kenneth Fields and deputy general manager R. W. Cooke have sent in their resignations recently; these will become effective as soon as new officials are chosen, but no later than July 1.

Mr. McCone, Strauss's successor on the Commission, was deputy to the Secretary of Defence in 1948, and in 1950 served as Under-Secretary of the Air Force. Since then he has been actively interested in the missile programme, and is said to have played an influential part in advising the President on missile and satellite policy. He is associated with several engineering and shipbuilding groups and is chairman of the Board of Pacific Far East Line and president of the Joshua Hendy Shipping Corporation.

INTERNATIONAL

Halden agreement signed

An agreement for the joint operation of Norway's 10 MW experimental boiling water reactor at Halden was signed on June 11 at Oslo by representatives from Norway, the UK, Austria, Denmark, Sweden, Switzerland and the six Euratom countries. Under the agreement, which is to run for three years from July 1, the countries will join with the Norwegian Institute for Atomenergi—the builders and owners of the reactor—in carrying out a programme of research and experiments on the understanding that funds will be made available by the national authorities.

The reactor, situated 120 km south of Oslo, is the only boiling water type in Europe and the first heavy water boiling reactor in the world. An International Committee will approve the £M1½ programme for studying the technical problems associated with this type and the work will be carried out by the Norwegian Institute with a team recruited from the participants under the supervision of a Technical Group. Representatives from the US have taken part in the discussions and have promised to collaborate by exchanging information and providing specialists.

IAEA starts first research study

The International Atomic Energy Agency's first research operation—an investigation into the factors controlling the distribution of fission products in the biosphere—is now under way. The contract for the work was recently awarded to the First Vienna University Chemical Institute, and it will be carried out by Dr Thomas Schönfield of the Radiochemistry department, aided by information and equipment supplied by the Agency. The one-year study forms part of the programme to develop health and safety measures and the contract is intended to serve as a model for similar operations in the future.

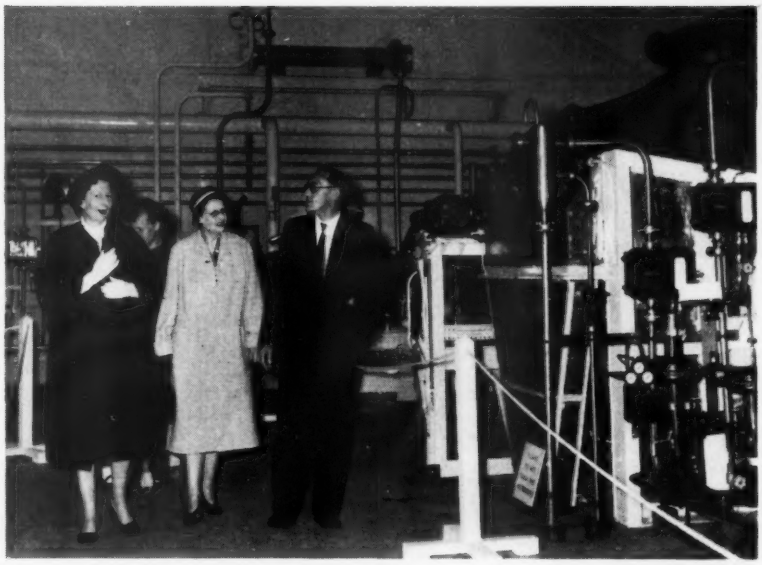
GENEVA

More technology this time

So many abstracts of papers—2,409 during March, April and May—have been received on such a wide variety of topics that the programme for the second international conference on uses of atomic energy which opens on September 1 has been revised and the total number of sessions raised from 65 to 77. Forty-five different countries and 4 international agencies have contributed; countries such as Mexico and Hungary, which submitted no papers in 1955 have sent in this time 5 and 28 respectively. Yugoslavia's offer is 56 against 7 in the previous conference, and West Germany's contribution has gone up from 2 to 65. Dr. Sigvard Eklung, Conference Secretary General, giving his impressions recently on the abstracts received, said there is a strong trend towards discussion of more technological problems compared with the heavy emphasis laid on the purely scientific side in 1955. He thought that the sessions on experience with nuclear power plants would attract a great deal of interest, even though the number of abstracts submitted was significantly small (six). On the other hand, almost 100 have been received on fusion, varying from wide national surveys to more detailed papers on different experimental approaches such as ZETA, DCX (US), Stellarator (US) or pure plasma physics. Types of marine reactors discussed will include those for the Russian icebreaker, the American *Savannah*, and the Japanese design for a submarine tanker. Other papers deal with methods for chemical processing of irradiated fuel elements, including cases where the uranium is canned in zirconium or stainless steel. Several countries have sent abstracts on gaseous diffusion methods of separating uranium isotopes, and the method developed in Germany using a separation nozzle will be discussed.

The abstracts are being scrutinized by a scientific Secretariat which is now recruited from 15 countries. Physics, reactors, chemistry and biology are each represented by 5 experts and geology by one. The main object of the work for some time to come will be the selection of papers for oral presentation. Though the main criterion is technical interest, an attempt will be made to get a reasonable geographical spread.

It has been decided that abbreviated versions of the proceedings will be printed this time in French, Russian and Spanish. The English version will, it is estimated, consist of 33 volumes, and will be ready by February of next year. John Martens of the US Argonne National Laboratory has been appointed chjef editor.



Springfields modernized

Opened on June 7 by Lady Plowden (left) wife of the AEA chairman, this new uranium concentrate dissolving section is among the extra facilities designed to modernize and increase the scope of the plant. Accompanied by works general manager Dr H. Rogan and his wife, she is seen walking past the rotary vacuum filters. In the background are the actual dissolvers

WORLDBRIEFS

Trawsfynydd Cost of the search for a nuclear power plant site in North Wales was £37,000, not counting work of the CEGB's own staff, states the Board in a report to Lord Mills, the Minister of Power. Besides Trawsfynydd—which cost £4,000 to survey—the only other suitable place found was at Edern.

New Zealand plan An institute of nuclear science is to be established. First step will be the purchase of a particle accelerator and the appointment of a director.

Winfrith Heath Committee presided over by Professor F. Perrin (France) and Sir John Cockcroft has approved £M10 programme for the experimental reactor to be jointly operated by the European Nuclear Energy Agency. Programme will be submitted to member Governments this summer to allow work to begin in January 1959.

Australia-US cooperation Eight US nuclear scientists visited Australia in June to follow up last year's bilateral agreement and decide on information to be exchanged. They also took part in the Sydney symposium on uses of atomic energy.

Argonne reactor hold-up Experimental boiling water reactor (EBWR) has been shut down because of excessive vibration in the turbine generator. Investigation showed one turbine blade and its shroud were missing.

American KEWB experiment The homogeneous kinetic experiment on water boilers increased power output from zero to 530 MWt in less than a second and shut itself off without damage in a recent experiment.

ORR run up to full power The US Oak Ridge Research Reactor (*Worldbriefs* May) has been operated at design power of 20 MWt.

Canadian NPD redesigned Construction of the Nuclear Power Demonstration reactor is expected to be resumed in July. Core is now to be a barrel-shaped horizontal aluminium tube 13 ft long, 15 ft dia. Through this run 132 aluminium tubes containing zirconium alloy pressure tubes housing fuel elements and heavy water 'coolant.'

Israel The nuclear research institute at Rekovot has now been opened.

Iceland The Icelandic Government has invited cooperation of OEEC in the building and exploitation of a heavy water plant and project is under discussion.

Sodium reactor experiment SRE near Los Angeles has been run up to full power of 20 MWt.

First Danish centre The £M4½ research station at Risö was opened on June 6. By the end of 1959 a British-made PLUTO and a US Foster Wheeler 5 MW tank type—with a new tank built by a Danish firm—will be added to the 5 kW DR1.

Although similar in design to Calder Hall, different construction methods are speeding completion of Britain's latest atomic plant

CHAPELCROSS POWER STATION

by P. KNOWLES, D.S.C., M.A., A.M.I.Mech.E., A.I.E.E.

Head of reactor department, Merz and McLellan, Consulting Engineers

THE CHAPELCROSS WORKS of the United Kingdom Atomic Energy Authority Industrial Group is situated three miles north-east of Annan, Dumfriesshire. It will contain four 180 tMW gas-cooled, graphite-moderated reactors of the Calder design and eight 23 MW turboalternators. The primary purpose of the works is the production of plutonium but it will have a net electrical output of about 140 MW.

More plutonium was needed

In February 1955, when construction of Calder Hall as a two-reactor station was well advanced, increased requirements for plutonium production were placed upon the Industrial Group as a matter of urgency. It was clear that the requirement could most expeditiously be met by reactors of the Calder Hall design and a decision to build six more such reactors was taken.

There was room on the Calder site for two further reactors only. However, it was very convenient that they should be sited there and the original station was accordingly re-named Calder A, and Calder B was laid out, virtually as a mirror image of the A station, alongside it. But a new site was necessary for the other four reactors.

The normal prudent approach to reactor siting suggested that the site should not be close to a densely populated area and that it should preferably be near the coast. A position within reasonably easy access of Windscale was desirable, because the fuel elements would have to be taken there for processing after irradiation. Thus the coastal areas of northern England and south-west Scotland were indicated and, since it was important that the reactors should be completed as soon as possible, a readily available site was required. Forty-eight possible sites were visited, and the best were investigated more thoroughly before the site near Annan was finally chosen in May 1955. Foundation conditions appeared to be good, with rock not far below the surface and, although direct cooling from the Solway was not possible, the River Annan could provide sufficient make-up water to support a cooling tower installation.

When the decision was taken to build six further reactors completion of construction of the first Calder Hall reactor was still fifteen months away and, with the doubling of the plant to be erected on the site, work was available to keep the Authority's construction staff busy there for another 3½ years. Further, when their work was completed, the team which had designed Calder was due to break up and to move to various new studies and projects. In the interests of speed the Authority determined not to undertake any new design of the reactors, other than that demanded by site conditions and by operational experience when available from Calder, and rather than attempt to recruit new staff to handle the Chapelcross project they appointed Merz and McLellan as consulting engineers for the power plant layout, services and civil engineering and as construction agents for the whole station. A small group was set up by the Authority at Risley to assume general direction of the project.

LAYOUT AND DESIGN

Chapelcross had the advantage of being planned as a four-reactor station from the outset, and the layout adopted is shown in figure 2. The station was placed in one corner of the site where access to the south and east was provided by existing roads and a main concrete runway afforded an axial road within the site, together with ample hard standing.

The four reactors are grouped in one line as two semi-detached pairs, adjacent and parallel to the main concrete runway, and the four cooling towers are symmetrically arranged in a parallel line on the other side of the runway. The single turbine house is symmetrically placed in front, that is to the south, of the reactors, not on the reactor line as at Calder, and the control block is on its forward face.

Foundation conditions

The decision, in the interest of speed of construction, to limit new design work on the reactor to a minimum, means that the differences between the reactors at Chapelcross and those at Calder are few. Most of the component parts of the reactors have been bought as repeat orders from the same large number of manufacturers who supplied them at Calder and in particular such major items as pressure vessels, blowers and ductwork and heat exchangers have been supplied again by Whessoe Ltd, C. A. Parsons & Co Ltd and Babcock & Wilcox Ltd, respectively. No attempt is made here to describe design features common to the Calder reactors (for descriptions, see References), but differences between the stations are concentrated upon.

PRINCIPAL ENGINEERING

Reactors

Fuel	natural uranium
Weight	130 tonnes
Number of fuel channels	1696
Number of control rod channels	112
Elements per channel	6
Pitch of channels	8 inches
Height of graphite	27 feet
Dia of graphite (across corners)	36 feet
Weight of graphite	1146 tons
Dia. of uranium rods	1·15 inches
Max cartridge surface temp.	766°F
Thermal output	180 MW

Gas circuit

Pressure vessel inside dia.	37 feet
Pressure vessel thickness	2·0 inches

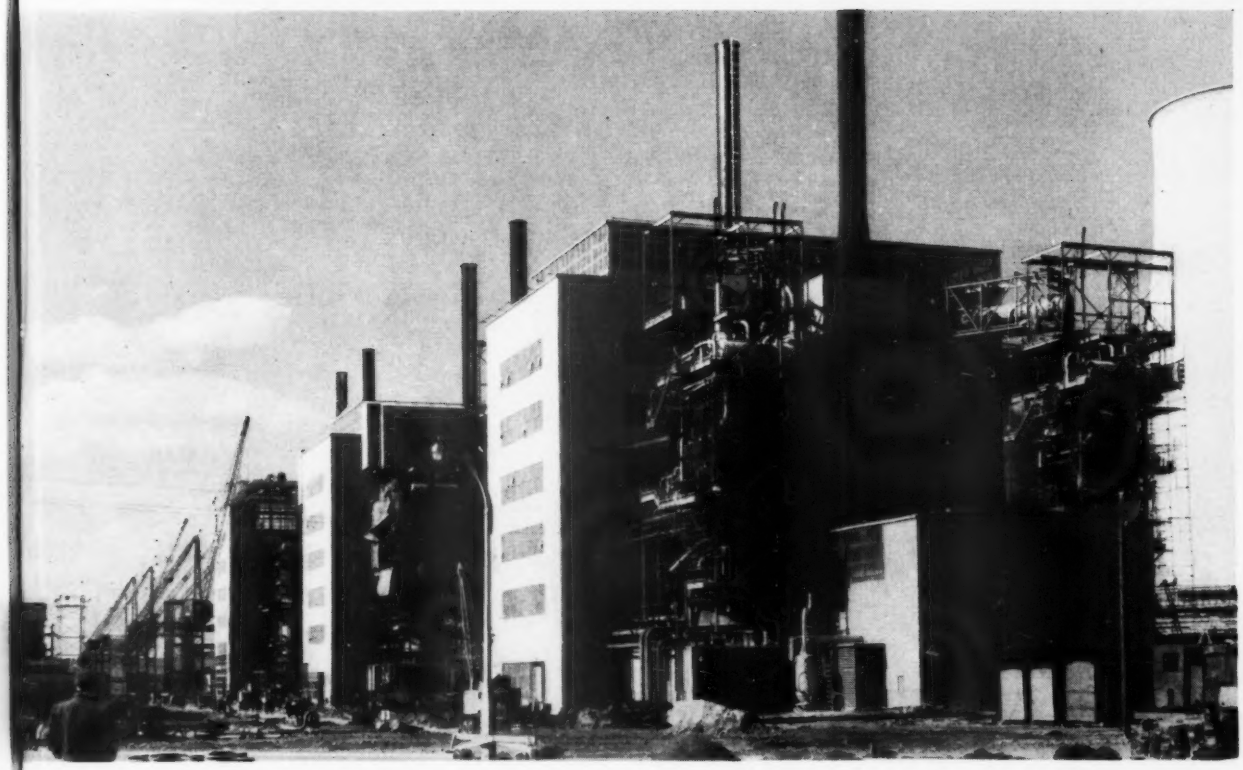


Fig 1 Very nearly complete, No 1 reactor will be followed by three others at three-monthly intervals

Preliminary trial pits on the airfield indicated that sandstone rock, with boulder clay above it, might be expected at a depth of about 20 ft, and the station was located on the south-east side of the site, leaving the north-west side free for future development. When foundation conditions under individual reactors were fully investigated by further pits and trial bores, the expected rock was found at depths between 15 and 25 ft under reactors 1 and 2, but at about 40 ft below reactor 3 and 60 ft below reactor 4.

Differential settlement

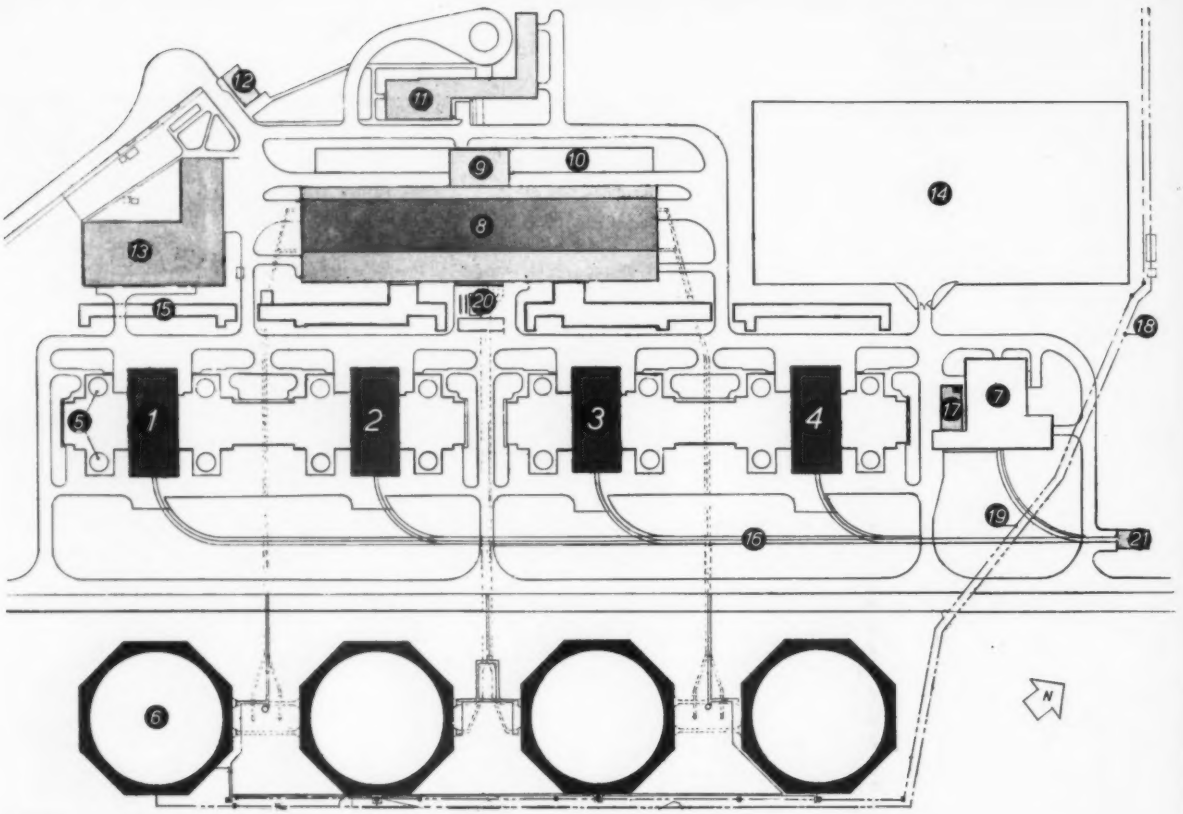
The main coolant ductwork for the Calder-type reactor is designed on the basis of a $\frac{1}{4}$ in. maximum differential settlement of the reactor vessel relative to the heat exchangers and it was obvious that this stringent condition could be met most cheaply and simply for reactors 1 and 2 by underwalling taken down to the rock. In excavating the foundations for the first reactor, however, it was found that the top surface of the rock was extremely uneven and heavily fractured. In view of this the original intention of excavating in trenches for the octagon (the main biological shield) and wing walls with independent pits for heat exchanger, blower and supplementary foundations had to be abandoned and it became necessary to excavate the whole area between the wing walls. This reduced the economic advantage of founding on rock and caused the alternative of raft-type foundations to be considered in the deeper rock conditions under reactors 3 and 4. Calder is founded on moraine with only small clay inclusions and it was possible to meet the settlement requirements there by founding each reactor on a very heavy raft with the heat exchangers and blowers on independent rafts alongside it. With clay overlying the rock at Chapelcross the differential settlement conditions could not be met with independent rafts and it was again much cheaper to take all foundations down to rock from reactor 3, than to use a single raft for reactor, heat exchanger and blower foundations. There was only a marginal case for founding reactor 4 on rock and in this case the reactors and heat exchangers were taken directly to rock and the blowers carried on beams supported from the heat exchanger foundations.

Other changes in the reactor buildings are slight. The abutting of long blower houses in pairs saves one gable end per reactor and also, as one overhead crane serves the double blower house, two cranes. The remaining six blower house cranes are rated at 20 tons compared with 15 tons in Calder A.

On the first Calder pressure vessels the 2 in. plates

DATA OF THE STATION

Working pressure	100 psig
Duct diameter	4·5 feet
Heat exchanger dia.	17 ft 6 in.
Gas circulator power	1495 h.p.
Gross circ. power per reactor	5·44 MW
Gas flow rate (per circuit)	500 lb/sec
Gas temperature at boiler inlet	637°F
Gas temperature at boiler outlet	275°F
Steam circuit	
H.P. flow per boiler	99,000 lb/h
H.P. steam pressure	195 psig
H.P. steam temperature	595°F
L.P. flow per boiler	29,650 lb/h
L.P. steam pressure	48 psig
L.P. steam temperature	350°F
Feed temperature	100°F
Electrical output (per set)	21 MW



Layout of the station shows:

1–4	Reactors	10	Generator transformer compound	16	Rail tracks to decay pond
5	Heat exchangers (4 per reactor)	11	Administration building	17	Personnel decontamination
6	Cooling towers (four)	12	Police lodge	18	24 in. inlet main
7	Cartridge cooling pond	13	Workshops	19	15 in. effluent drain
8	Turbine hall	14	SSEB 132 kV compound	20	Carbon dioxide plant
9	Control room	15	Steam pipe trenches	21	Loco shed

This is how a Chapelcross reactor operates *(see coloured drawing opposite)*

The centre of the reactor or core is a pile of graphite blocks (6) of special shape arranged in an ingenious way to cope with thermal expansion and growth under neutron irradiation. These blocks rest on a massive egg-box grid (23) inside the cylindrical steel pressure vessel (31). Nearly all the graphite blocks have holes through them and these are arranged so that complete vertical channels run through the core from top to bottom. In these channels are the fuel elements (19), which are rods of natural uranium hermetically sealed into finned cans of special magnesium alloy. When a 'critical mass' of these elements has been assembled the uranium fission becomes self-sustaining and heat is produced. About 50 control rods of special neutron-absorbing steel (15) held by cables can be raised or lowered by motors (36) in other channels through the graphite to control the reaction.

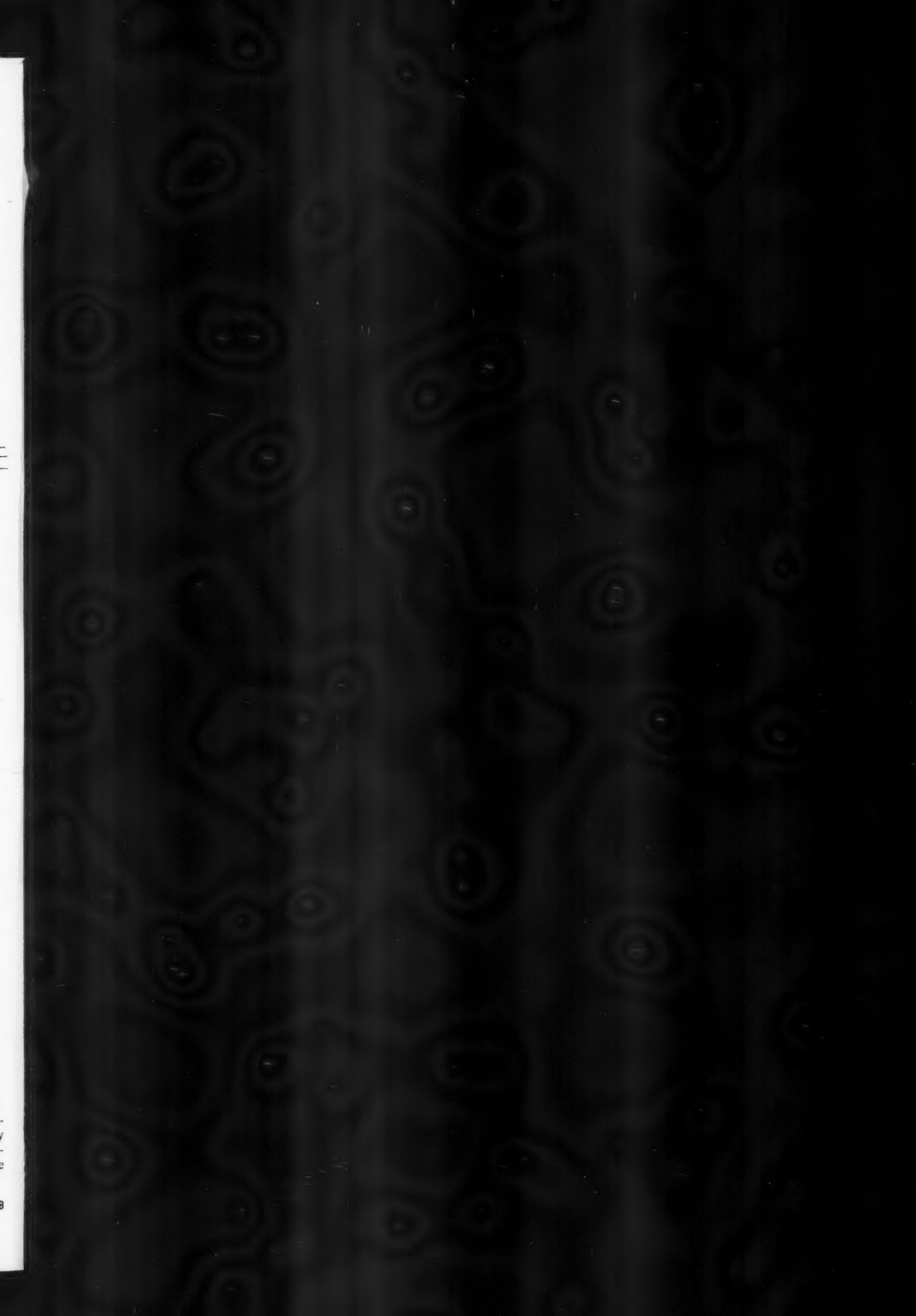
The heat produced in the pile has to be removed so that it can be usefully employed. This is done by blowing high-pressure carbon dioxide gas through the core by means of powerful circulators (50). The gas enters (20) at the bottom of the pressure vessel, from whence it flows up the graphite channels, becoming heated by contact with the hot cartridges. It then leaves at the top of the pressure vessel (13) and passes over to one of four heat exchangers in which it flows down over miles of closely packed tubing (63 to 70) through which water and steam are flowing. From the bottom of the heat-exchanger (84) the gas is returned to the gas blower.

The steam produced in the heat exchangers is at two pressures—because this is the most economical system in a plant of this kind—and passed through underground pipes to the turbine hall (4) in which electricity is generated in turboalternators (92, 93). The condensers (91) are cooled by the conspicuous cooling towers (5).

To protect the operations staff and the public, the reactor pressure vessel is contained inside a concrete biological shield (33) many feet thick and, to protect the concrete from the heating effect of the radiation, it is faced inside by a thick steel-plate thermal shield (32). The space between the reactor vessel and the shield is cooled by air which is discharged through the stacks (35).

Fresh fuel is loaded by means of special machines (7) and burnt up cartridges are removed by other machines (8)—similar, but heavily shielded since the cartridges are now strongly radioactive. After unloading, the cartridges are stored under water for about 3 months before chemical reprocessing.

carrying each group of four sampling plant tubes were reinforced by a single external 1 in. thick compensating plate but it was found that this caused a stress concentration in the shell between the reinforcing plate and the 4½ in. thick outlet duct reinforcement plate. In later vessels a single 3 in. thick plate has been introduced by Whessoe, adequate to take the sample plant and thermocouple tubes without additional reinforcement. This plate



The United Kingdom Atomic Ener

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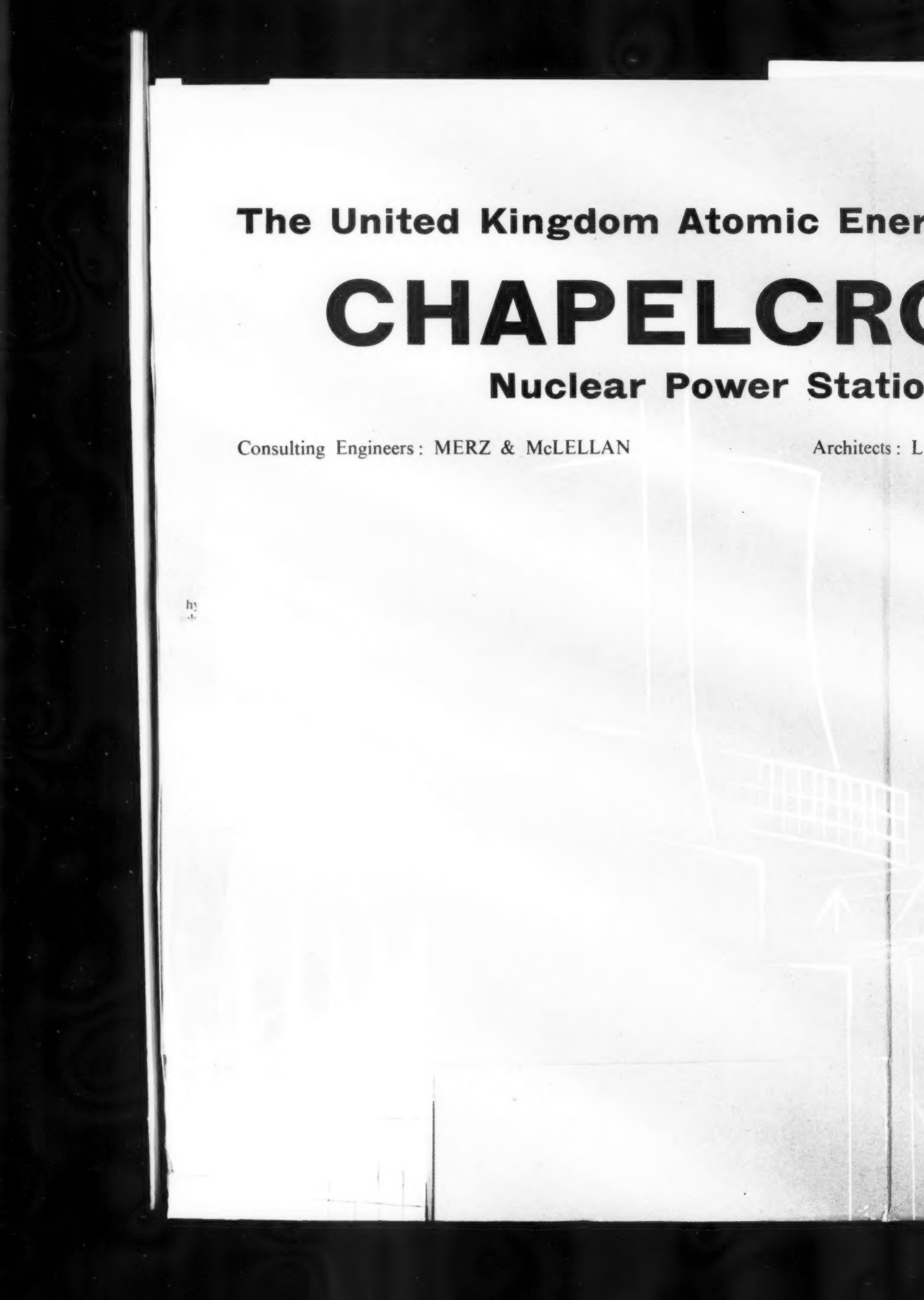
Nuclear Power Statio

Consulting Engineers: MERZ & McLELLAN

Architects: L



Energy Authority

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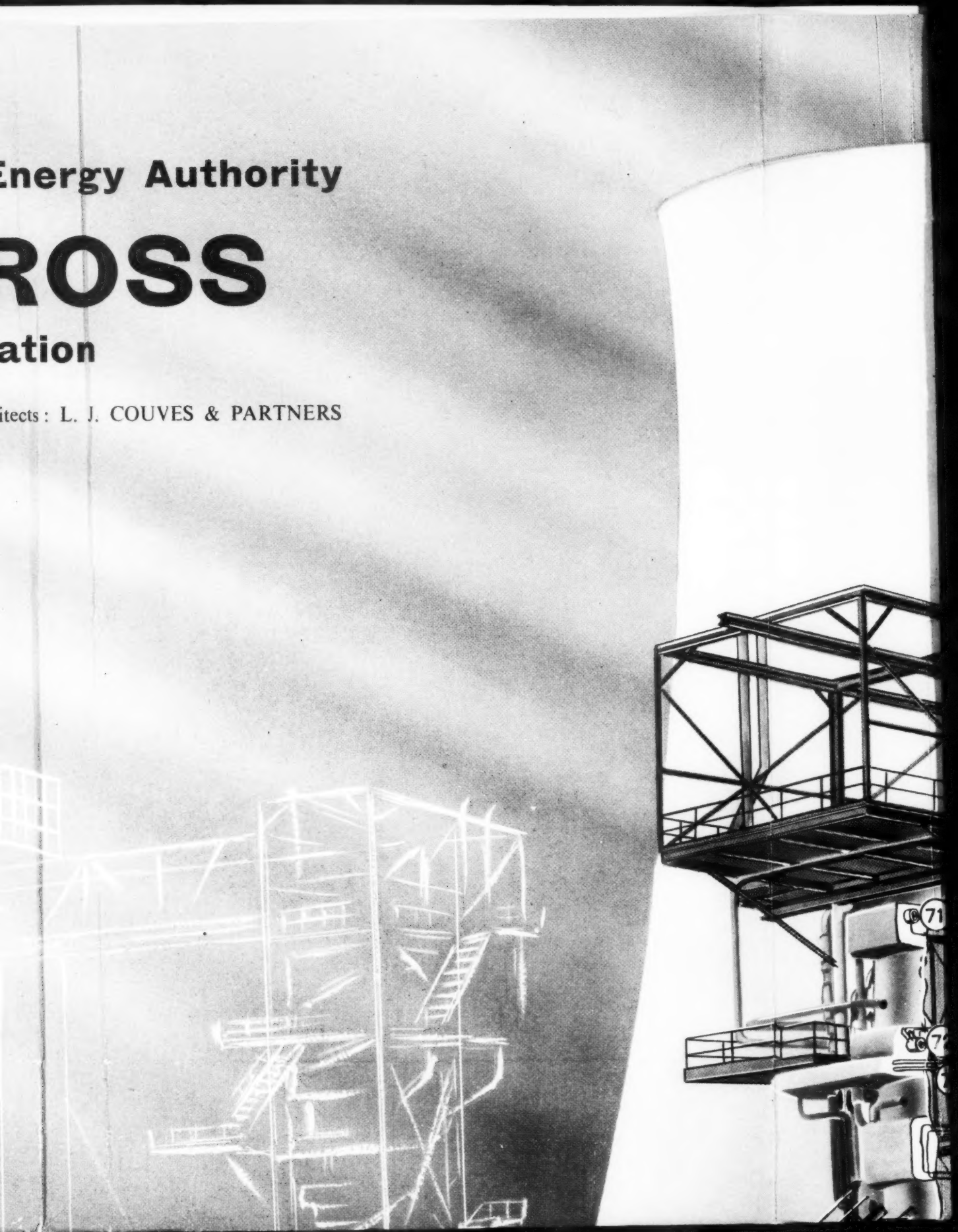
itects : L. J. COUVES & PARTNERS



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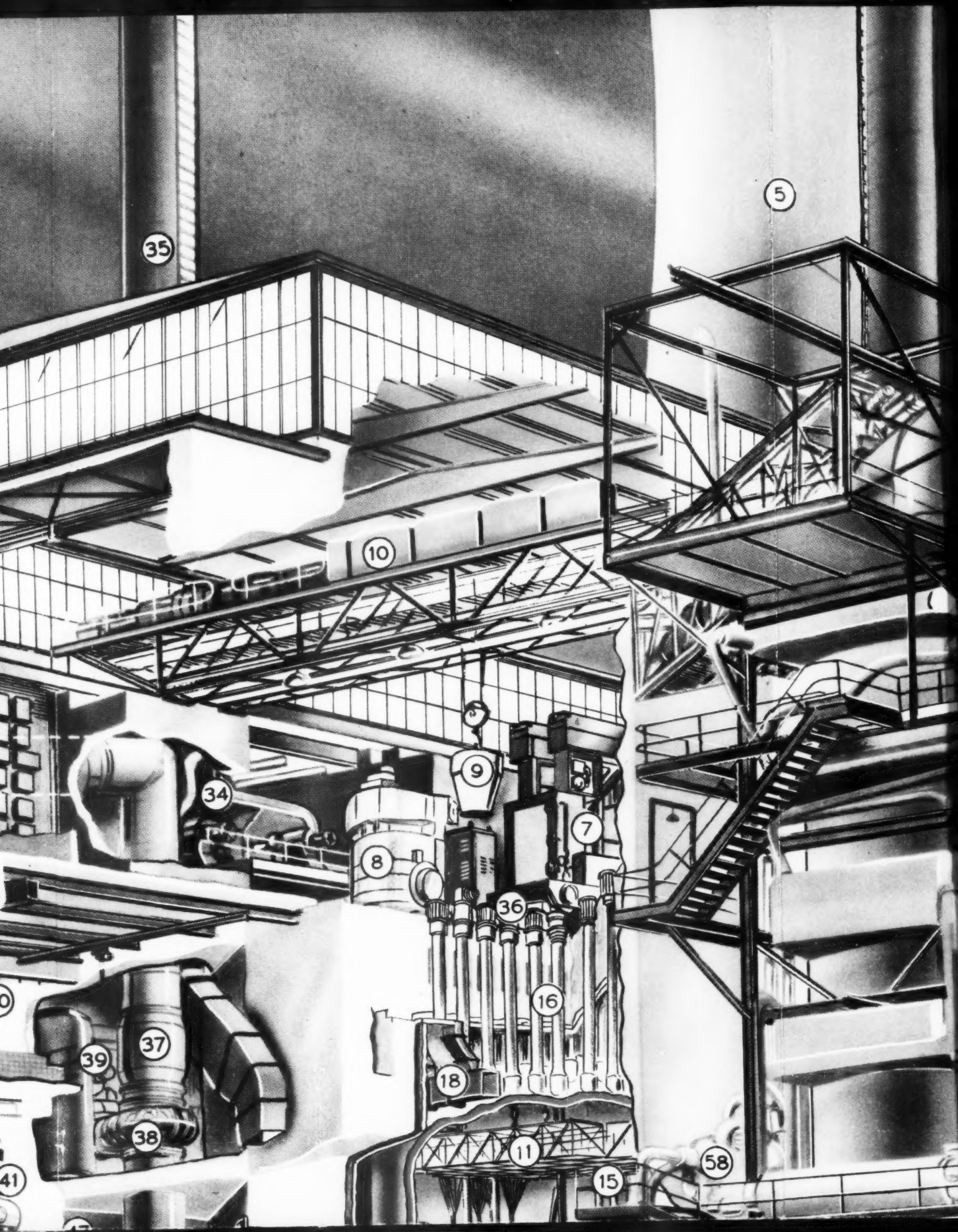
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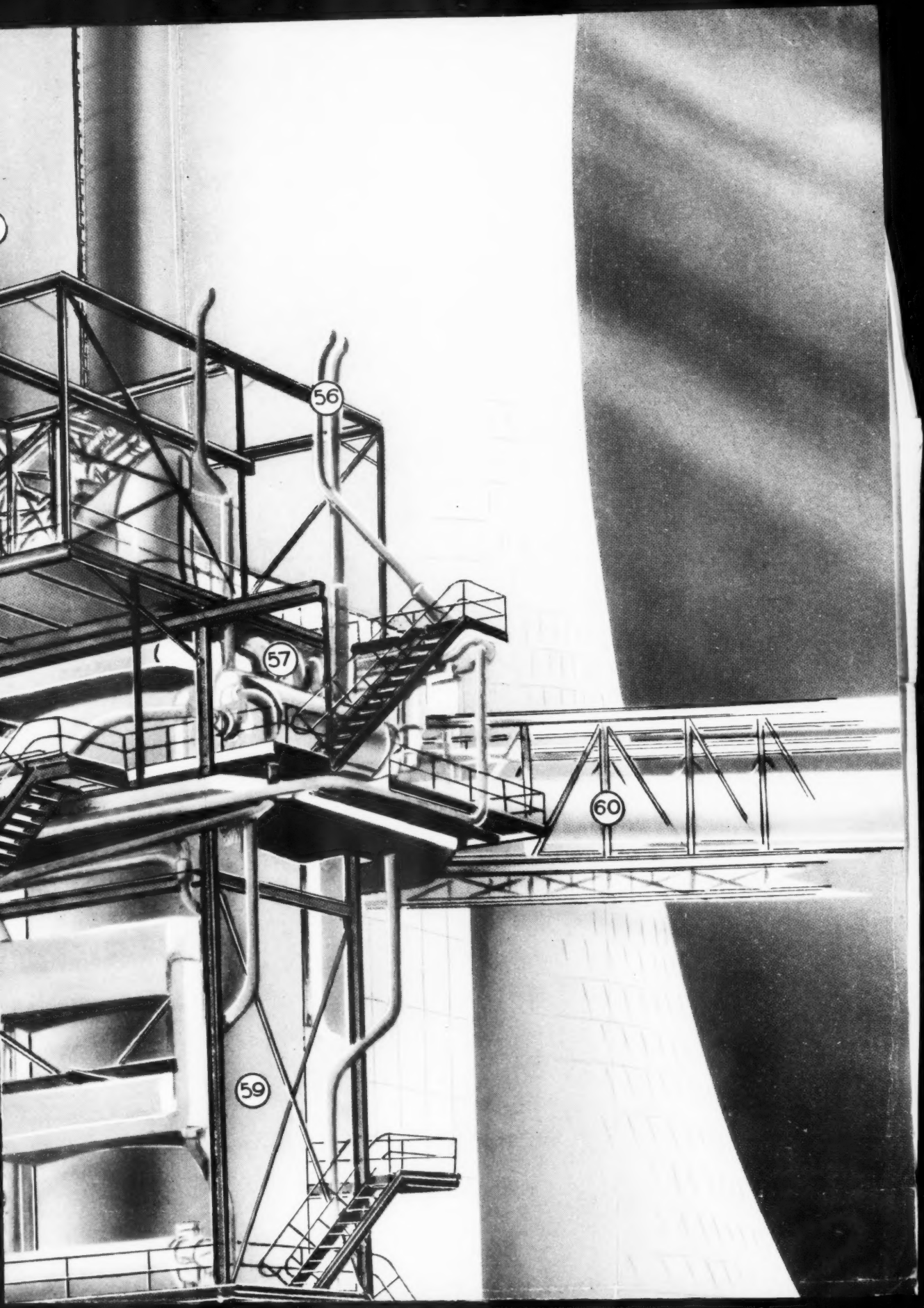
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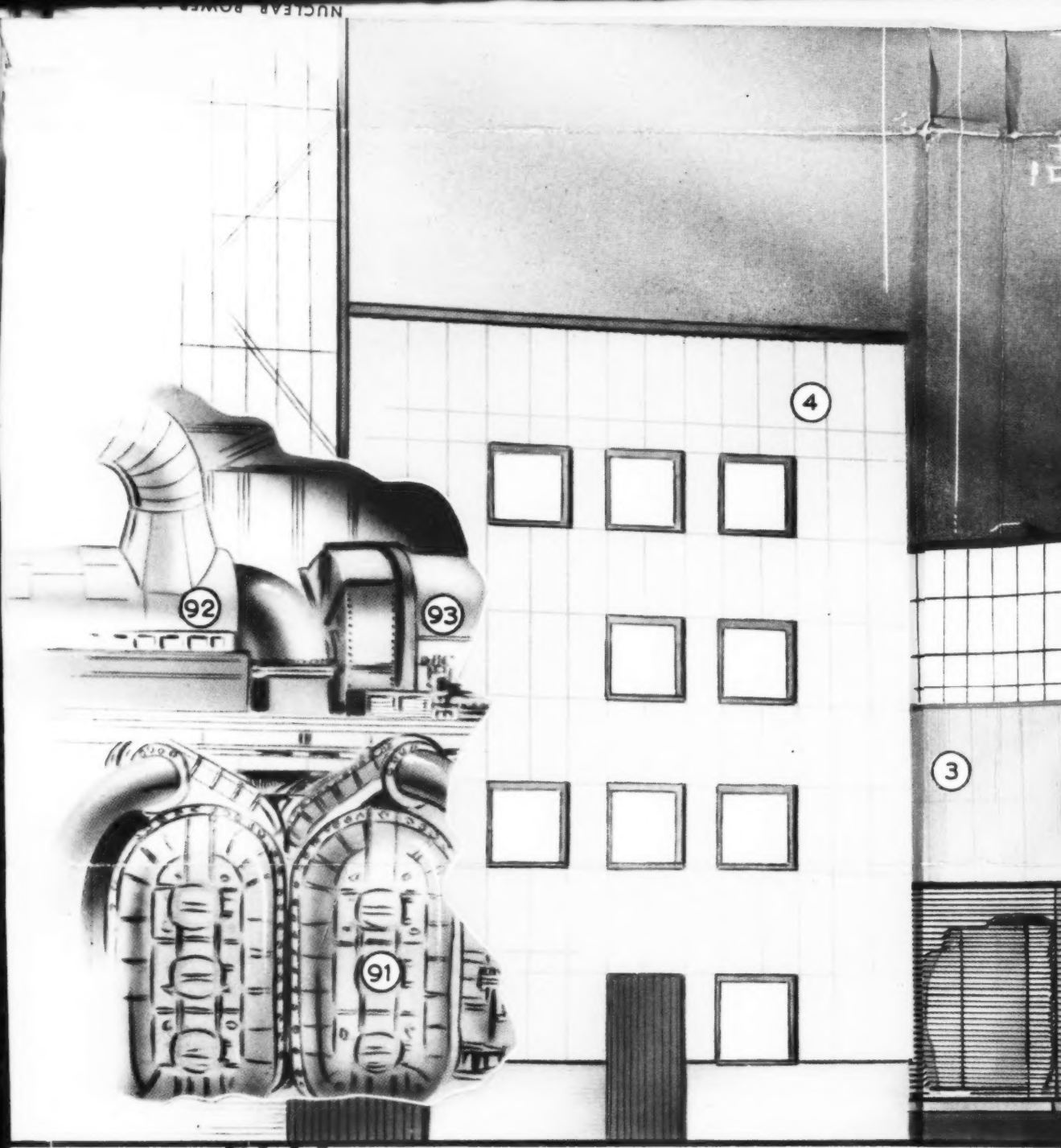
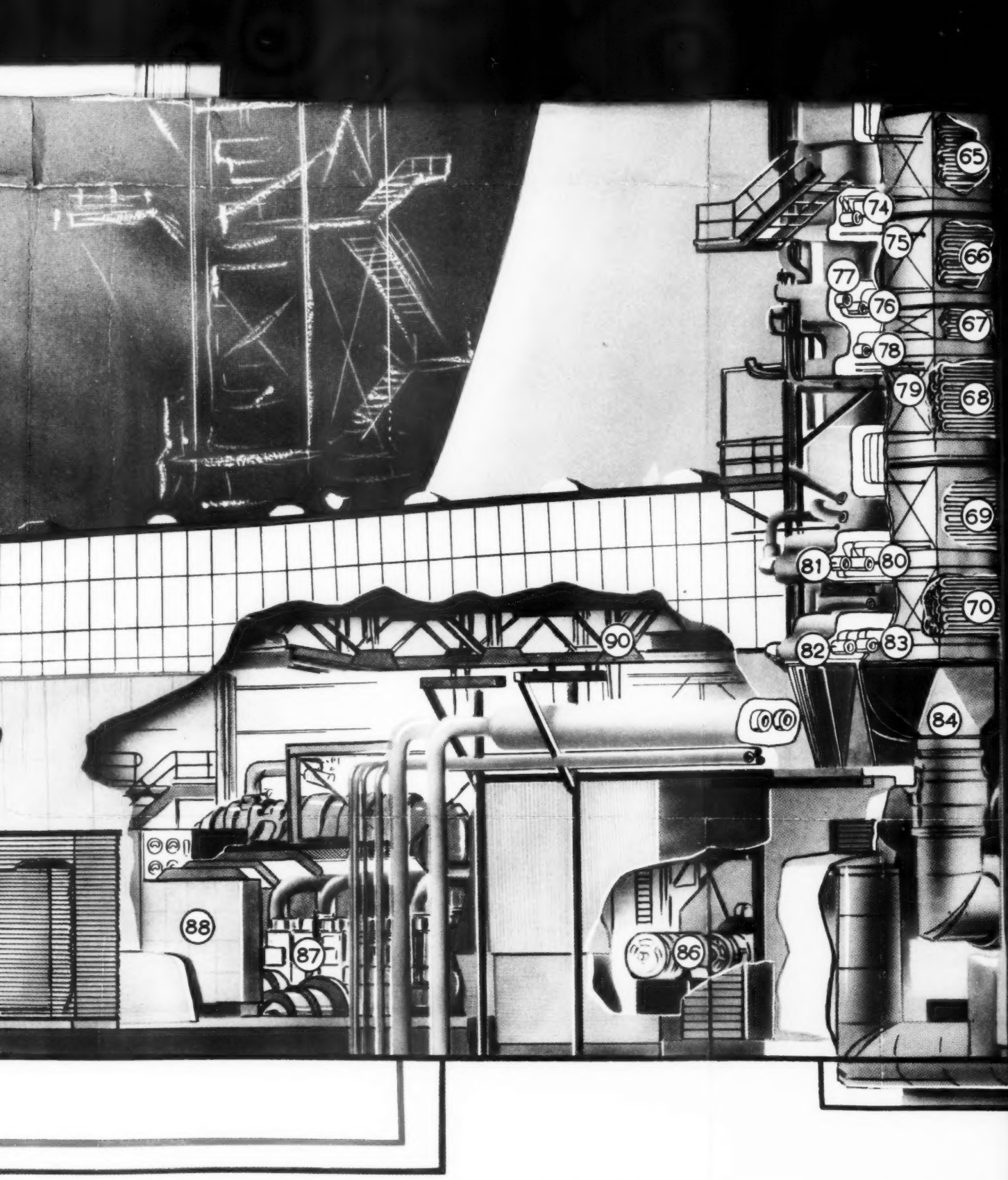
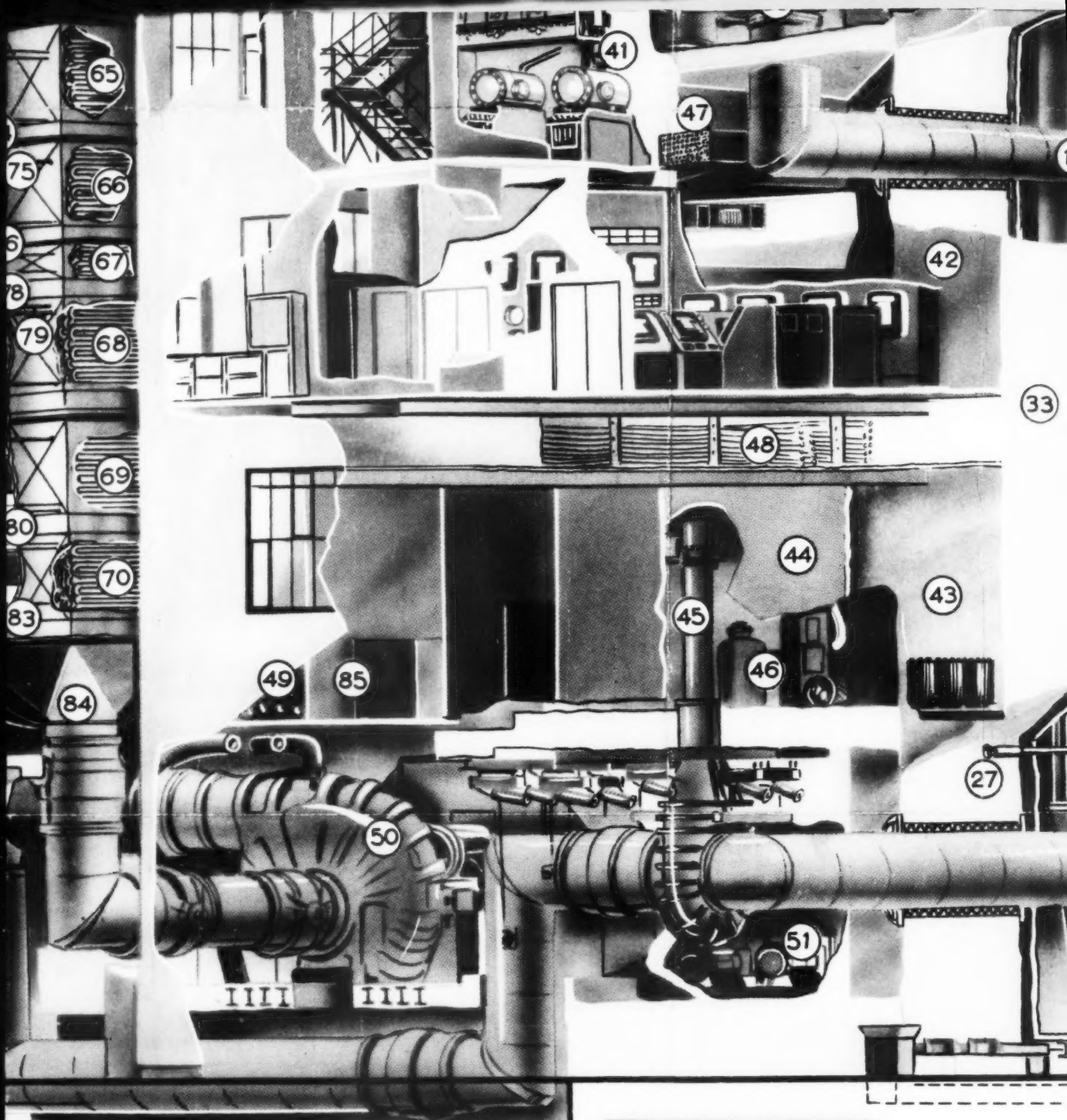


KEY

1. No 1 reactor building
2. Short blower house
3. Long blower house
4. Turbine hall
5. Cooling tower No 1
6. Graphite moderator
7. Charge machine
8. Discharge machine
9. Fuel basket
10. Overhead electric travelling cra
11. Warren girder, for gas samplinges
12. Sampling outlet tubes
13. Gas outlet duct, No 4
14. Charging chute
15. C
16. C
17. C
18. A
19. F
20. F
21. F



15. Control rod
16. Charge tubes
17. Charge pan
18. Air cooling duct
19. Fuel elements
20. Fuel element support
21. Fuel element support boss
22. Graphite support bearings
23. Base support plates
24. Wigner probe
25. Gas seal
26. Core support grid
27. Viewing tube
28. Gas inlet duct from No 4 boiler
29. Pressure vessel support frame
30. Base plate grillage
31. Thermal insulation
32. Thermal shield
33. Biological shield
34. Shield cooling fans
35. Shield cooling stack



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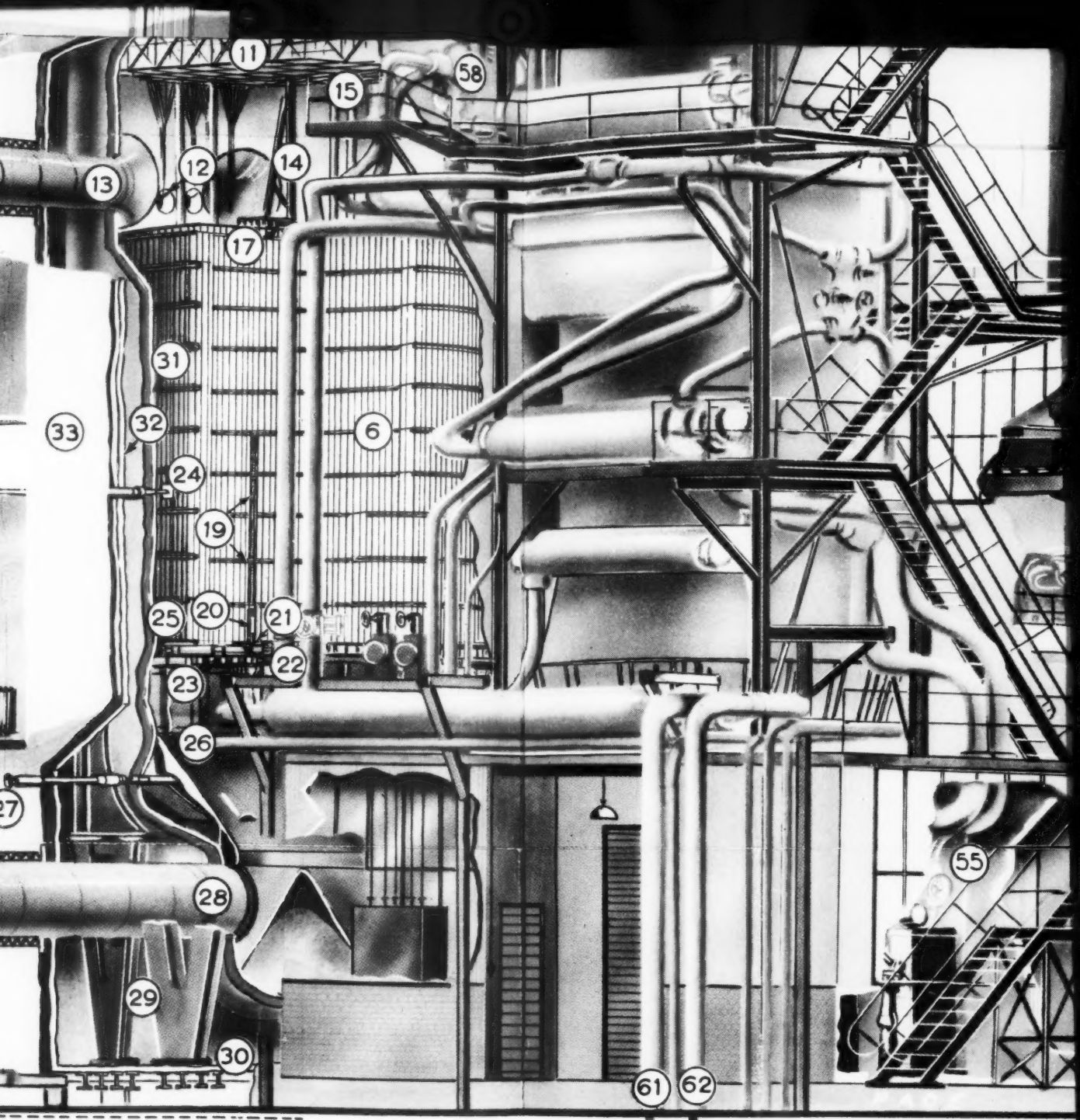
3 Percy St, London, W 1, England

port frame

36. Control rod actuators
37. Gimbal bellows joint
38. Upper gas isolating valve, No 4 circuit
39. Valve chamber
40. Fuel element preparation room
41. Gas sampling plant room
42. Control room
43. Battery room
44. Switch room
45. Lower gas isolating valve, No 4 circuit
46. Gas drier
47. Gas sampling pipes
48. Cable gallery
49. Carbon dioxide room
50. Main
51. Circul
52. Blow-
53. Air fil
54. Gas cy
55. Boiler
56. Safety



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60. Main circulator No 4
61. Circulator oil tanks, coolers and pumps
62. Blow-down tank
63. Air filter house
64. Gas cyclone and filter room
65. Boiler circulator pump house
66. Safety valve vents
57. High pressure steam drum
58. Low pressure steam drum
59. Boiler No 1
60. Duct to boiler No 2
61. HP steam main to turbine hall
62. LP steam main to turbine hall
63. HP superheater bank, boiler No 4
64. HP evaporator bank (upper)
65. HP evaporator bank (lower)
66. HP, HT economizer bank
67. LP superheater bank
68. LP evaporator bank (upper)
69. LP evaporator bank (lower)
70. HP and LP mixed economizer bank
71. Superheater outlet
72. Superheater inlet
73. HP evaporator outlet
74. HP evaporator inlet
75. HP, HT economizer outlet
76. HP, HT economizer inlet
77. LP superheater outlet
78. LP superheater inlet

eam drum
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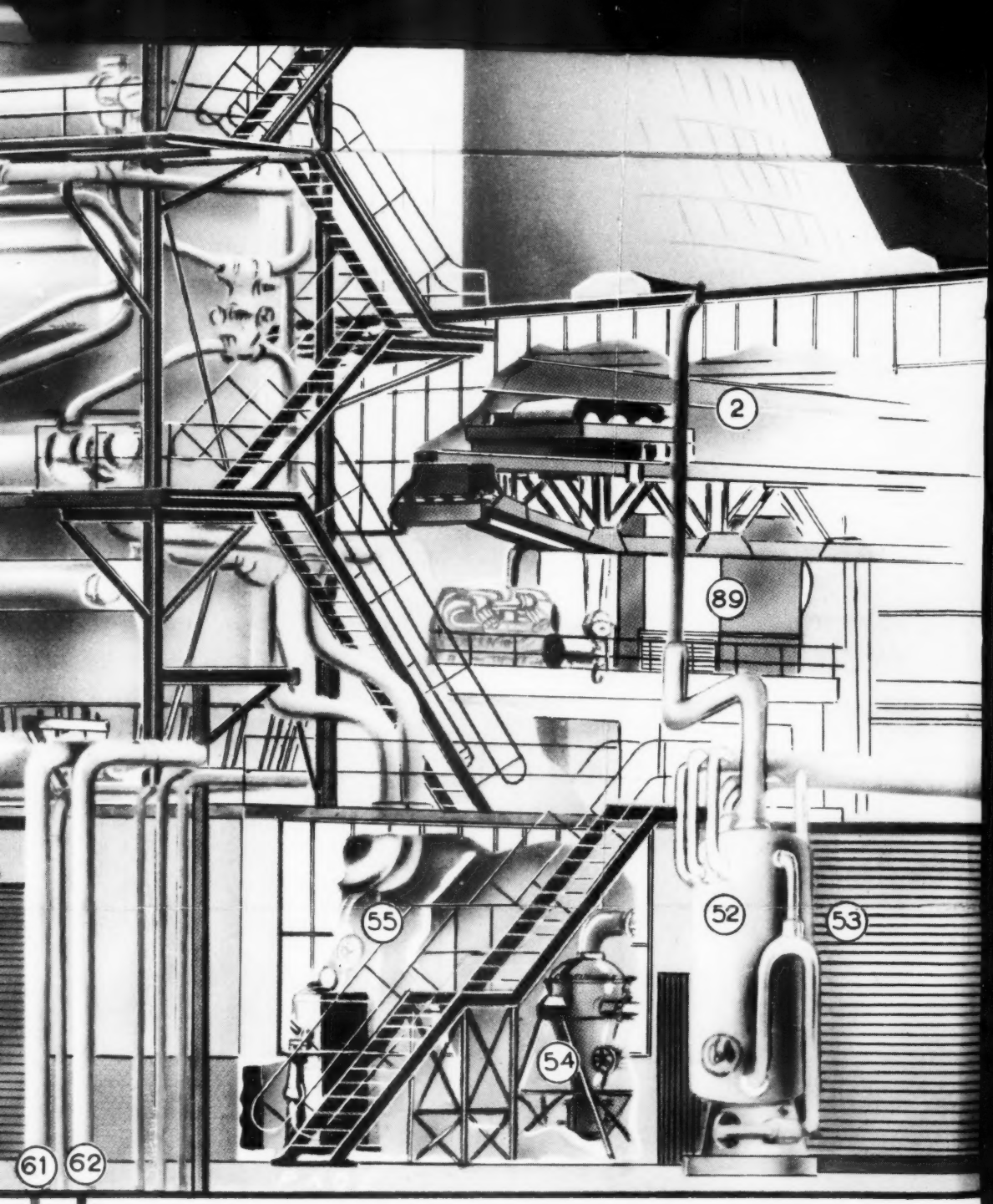
o 2
turbine hall
turbine hall
ank, boiler No 4



64. HP evaporator bank (upper)
65. HP evaporator bank (lower)
66. HP, HT economizer bank
67. LP superheater bank
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70. HP and LP mixed economizer bank
71. Superheater outlet
72. Superheater inlet
73. HP evaporator outlet
74. HP evaporator inlet
75. HP, HT economizer outlet
76. HP, HT economizer inlet
77. LP superheater outlet
78. LP superheater inlet
79. LP evaporator outlet
80. LP evaporator inlet
81. Mixed economizer outlet
82. Mixed economizer inlet
83. HP mixed economizer inlet
84. Gas outlet to circulator No 4
85. Battery charging room
86. No 4 Ward-Leonard set
87. Standby diesel generators
88. Diesel control panel
89. Water coolers
90. Overhead electric travelling crane
91. Main condenser
92. Turbine, low pressure end
93. Alternator

No 4

Fig 3 In the construction of the concrete biological shields, prefabricated climbing shuttering is used. Note the shielded lift shaft down which the irradiated fuel will be lowered from the pile cap

is welded straight to the 4½ in. thick plate at each end.

Some minor improvements in design have been effected in control rod mechanisms and supply systems and facilities for fuel element and moderator temperature measurement have been extended. Carbon dioxide supplies to individual reactors are now metered. The discharge-basket handling facilities have disappeared from the reactor discharge annexe and the bogie carrying the discharge-coffin is hydraulically manipulated within the precincts of the large well shield doors, both changes arising in consequence of Chapelcross having its own decay pond, described in detail later.

Gas handling plant

One carbon dioxide storage plant serves all four reactors and is situated to the rear of the turbine house. There are five 20-ton storage tanks for the liquid and the pressure in them is held in the vicinity of 300 psig by Freon-12-cooled coils in the gas space, the unit refrigerator of each tank cutting in automatically when the tank pressure rises to 305 psig and dropping out when the pressure falls to 295 psig. The tanks are connected to a common liquid manifold feeding a battery of six 3-ton/h steam-heated evaporators arranged in parallel. The plant is designed, as a maximum load, to charge two reactors simultaneously at a rate of eight tons per hour each, but its normal duty will be to supply the small amount of carbon dioxide continuously demanded by the burst element detection gear of all working reactors, and occasionally to top up a working reactor.

IRRADIATED FUEL HANDLING

Fuel elements discharged from Chapelcross will be stored in a decay pond there for a few months, until their activity has decreased sufficiently for them to be accepted by the Windscale chemical separation plant and also for them to be transported to Windscale in large batches without use of a disproportionately-thick transport coffin. The pond will be for storage only, all decanning and similar preliminaries to chemical processing being carried out at Windscale. Calder, of course, does not have a pond but relies on the adjacent Windscale facilities, and this represents one of the major differences between the two Works.

The pond layout is indicated in figure 5. There are two similar half-ponds each with a transfer and an exit bay at one end and a 'burst' bay at the other end. All handling of fuel elements takes place under water and extensive under-water lighting is provided in the handling bays. The water is 17 ft 9 in. deep and there is no connexion on the water side between the two halves. The transfer and exit bays and the entrances to them are covered but the remainder of the ponds and the burst bays are open.

Coffin decontamination

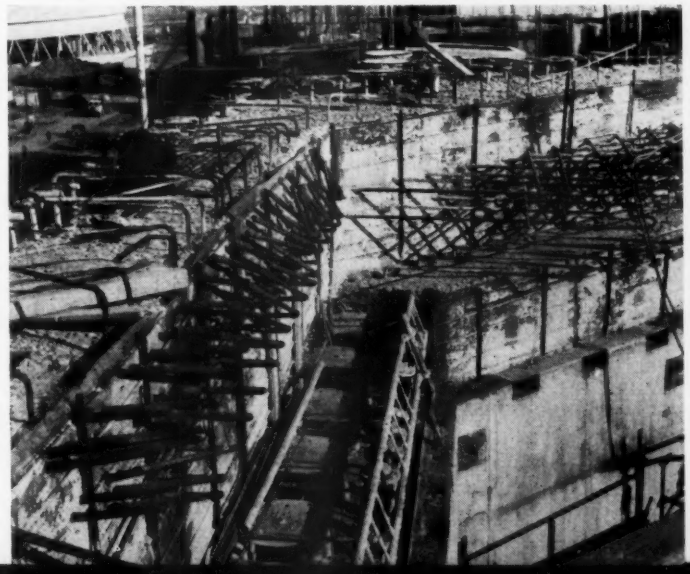
As at Calder, the reactor discharge machine lowers a stainless-steel basket of 24 irradiated cartridges into a transit coffin waiting, in a shielded chamber, on a bogie at the base of the discharge well. The bogie runs on standard-gauge rails and, at Chapelcross, is hydraulically manipulated out of the chamber, picking up the coffin lid before emerging. It is then taken in tow by a diesel locomotive drawn over to the pond and reversed into the transit coffin loading bay. The coffin-handling crane, which runs on rails over the loading, transfer and exit bays, is brought into position, its main hoist is connected to the coffin lifting trunnions and a fixed-length auxiliary-hoist chain attached to the coffin lid. The coffin is lifted, traversed over and lowered into the transfer bay of either half-pond. The fixed length chain reaches the limit of its travel well under water but before the coffin grounds, thereby lifting the lid, which is then deflected clear of the coffin. There is a travelling platform in each bay which is then moved over the coffin and, by means of an hydraulically-operated hoist mounted on the platform, lifts the basket out of the coffin, traverses with it down the transfer bay clear of the coffin, and then lowers it to within 3 inches of the pond floor ready for the debasketing operation. The coffin lid is then returned from the deflected position when the coffin is lifted out of the pond, picking up the lid as it rises, and traversed over to one of two coffin decontamination vats. There the coffin is sprayed first with decontaminating solution and then with town water before being monitored for activity. After monitoring has shown the coffin contamination level to be satisfactory it is transferred by the coffin-handling crane back to the transit coffin loading bay and loaded onto a bogie ready for return to the reactor.

Manual debasketing

The decontaminating solution is continuously recirculated during the spraying of the coffins but the system is purged periodically by bleeding off ten pct of the solution to a detention tank, mentioned later, and making up with fresh solution. The town water used for washing goes to a drain sump whence it is pumped to the detention tank.

The irradiated fuel elements in the discharge basket are

Fig 4 Round the top of the biological shield built-in ducting is installed as part of the shield cooling system



How irradiated fuel elements are handled at Chapelcross (Fig 5)

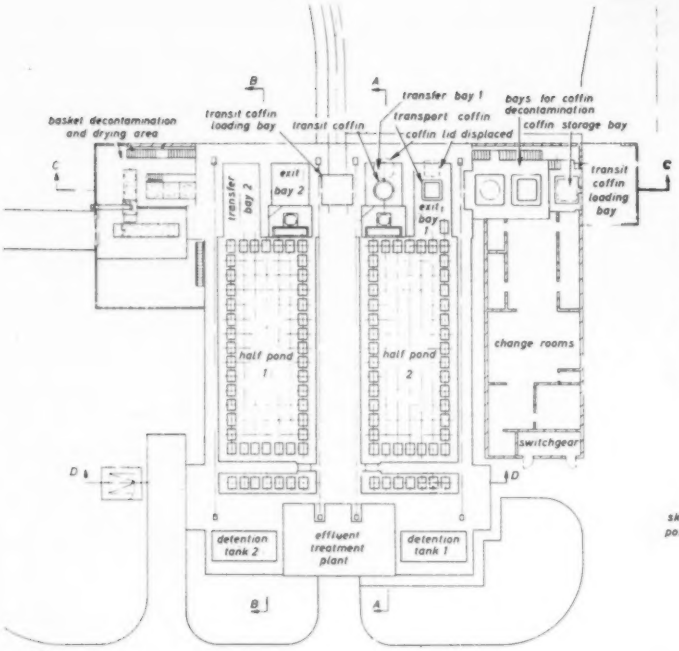
Elements are stored under water for about 3 months before transporting them to Windscale for decanning and chemical processing. The figure shows :

1 Irradiated fuel elements from the reactors arrive by rail at the ponds in baskets inside transport coffins

2 Under water, the lid of the coffin is removed and the basket extracted by the hydraulically-operated platform hoist. The rods are now debasketed under water and lifted into the storage skips by power-assisted tongs

3 Burst cartidges are treated separately and taken in a general purpose coffin to the special ponds at the end of the main ponds

4 Special arrangements are provided for decontaminating the baskets and coffins before they are returned for further service



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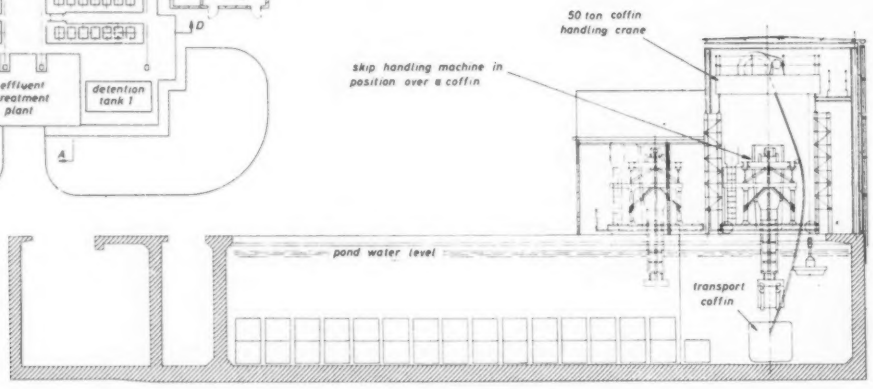

section through B-B

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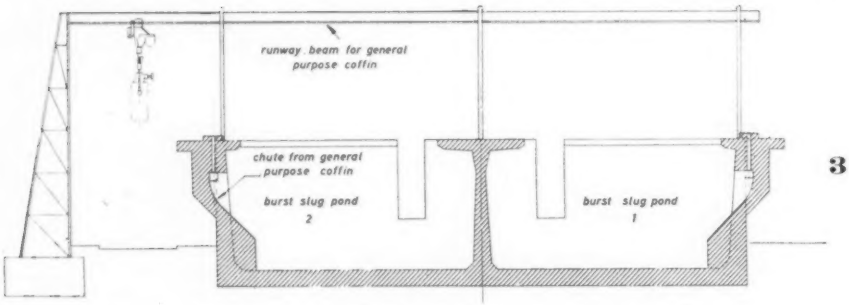

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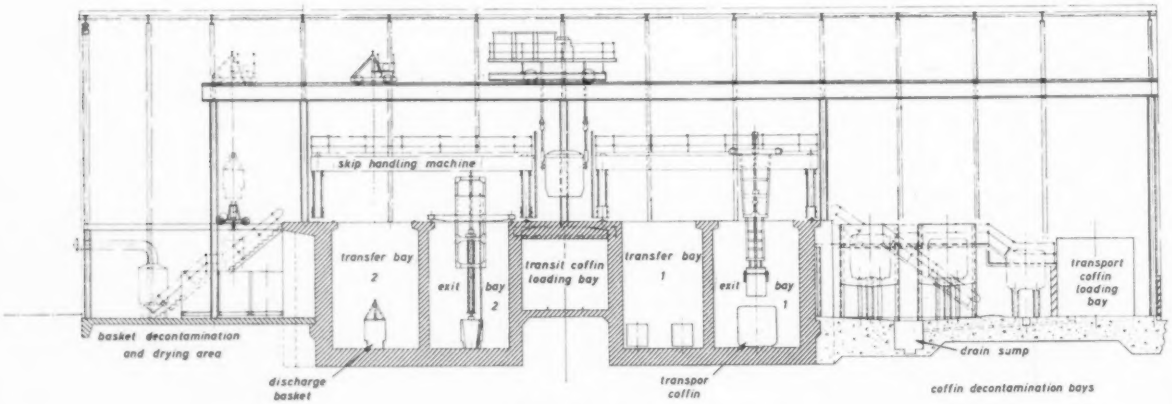

section through C-C

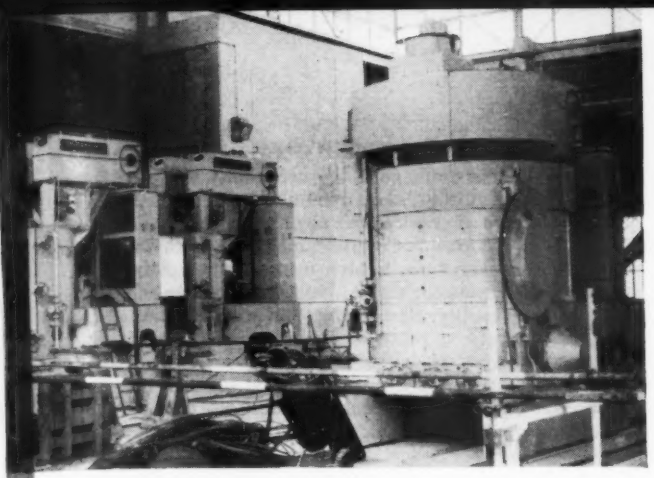

Fig 6 Unloading of irradiated fuel elements from the reactor is done by heavily shielded discharging machines (nearest), on the pile cap. Beyond, are two similar but unshielded machines for loading fresh fuel

in an inclined position, as shown in figure 7, with their lower ends resting on a lip on the basket base. When the basket is in the debasketing position the pond operators take hold of the top of each element in turn, using long tongs some of which are power assisted, and raise it an inch or so. This allows the element to swing clear of the lip into the vertical position so that, when it is lowered, the tail passes through the open bottom of the basket and rests on the pond floor. When all elements have been cleared of the lip the basket is raised clear by the travelling platform hoist, when the elements fall from the vertical position onto the pond floor.

The basket is transferred to the back of the transfer bay into the position vacated by the coffin and is picked up from there by the basket-handling crane, which runs on the same rails as the coffin-handling crane. A protective device is provided to prevent the basket-handling crane from lifting a basket if any of the fuel elements are still retained in it. The basket is lifted clear of the water, traversed to the basket decontaminating and drying area and completely immersed in one of two vats of decontamination fluid. The fluid is swirled by re-circulation and the basket is agitated to increase the efficiency of decontamination and then the basket is transferred and washed by similar methods in a vat of town water. Finally the basket is transferred to a roller conveyor, passed through a drying oven, monitored and placed in store. It is returned to the reactor, as required, by van.

Skip handling

The elements released from the basket fall to the pond floor between positions for two storage skips. The skips are rectangular open-topped containers, 3 ft 10 in. long by 2 ft 8 in. wide and 3 ft 7 in. deep, made of mild steel painted with ICI *Permobel* abrasion-resisting paint and each designed to contain about 140 elements. The elements are lifted from the pond floor by long power-assisted tongs manipulated from the travelling platform and carefully placed into the skips.

Two skip-handling machines are provided, one for each pond. They transfer skips between the transfer and exit bays and the main pond and burst bays. The machines are Goliath-type cranes with an hydraulically-operated hoist mounted under the crab, and they can be very accurately located in both plan dimensions so that the skips can always be placed on, or picked up from, any of a fixed lattice of positions on the pond floor.

When a skip has been filled with elements in the transfer bay, the skip-handling machine is driven into position over it, and lifts it just high enough to clear other skips on the pond floor. In this way as much water as possible is retained above the skip as a radiation shield. It is then transferred to a vacant station out in the pond and an empty skip picked up from another station to replace it in the transfer bay. Each half-pond has 105 skip stations, and there is provision for double stacking of skips if required.

Individual element handling

Special elements, such as thermocouple elements, are delivered to the pond after irradiation, one at a time, in general-purpose coffins. The elements discharged from a channel containing a burst element are similarly delivered. The general-purpose coffins are conveyed by transporter lorry to the burst bay end of the ponds, off-loaded by electric hoist working from an overhead runway beam, traversed and lowered onto one of two coffin parking stations situated at the outboard ends of the two burst bays. When the coffins are in place on the stations, their bottom doors can be opened and their contents lowered through a chute into a normal skip waiting below. Devices are provided for detaching thermocouple cables from special elements during the lowering process and also for depositing the detached cable into the skip. The general purpose coffins are thus not immersed in pond water and no provision is made for their decontamination on a routine basis. Skips, when full, are moved out onto one of the seven stations provided in each burst bay, or into the main pond. Double stacking of skips is possible also in the burst bay.

When handling skips into and out of the burst bay, the skip and hoist of the skip-handling machine pass through a gate in the wall dividing the bay from the remainder of the pond. The division tends to confine to the burst bay any extensive contamination which might arise from a bad burst.

Pond water treatment

Irradiated fuel elements are conveyed to Windscale in transport coffins, which take a skip at a time, on road transporters. The transporters arrive at the pond, complete with transport coffin containing an empty skip, and are

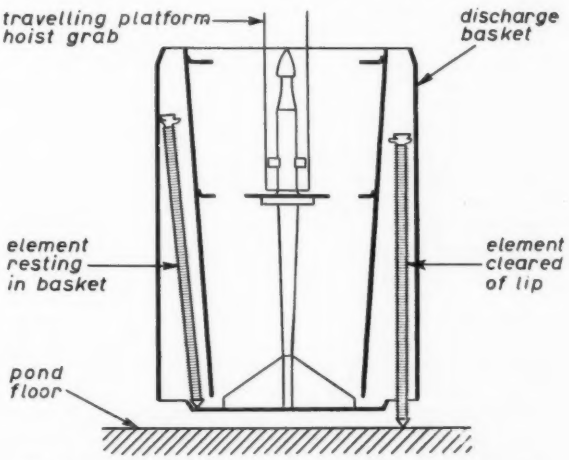

Fig 7 When the loaded fuel basket reaches the bottom of the cooling pond the elements are lifted clear by long manipulators. The basket is then hoisted and the elements fall clear

positioned in the transport coffin loading bay. The coffin is lifted off by the coffin handling crane and lowered into one of two exit bays, its lid being lifted and deflected exactly as for the transit coffins. The skip handling

machine then removes the empty skip from the coffin, deposits it in a vacant station in the pond, picks up a full skip the contents of which have undergone their normal decay period and places it in the coffin. The coffin is lifted and its lid replaced and goes through the same decontamination, wash and monitor routine endured by the transit coffins and is then loaded on to a waiting transporter and taken to Windscale.

Water is eminently suitable as a shielding material for irradiated fuel elements because it is transparent and cheap and can be treated to render it non-corrosive to the elements stored in it. Of these virtues the importance to the pond operators of being able to see directly the elements on which they are working cannot be over-emphasized, and pond water treatment is practised just as much to keep the water clear as to render it non-corrosive. Make-up water for the pond is town water from the Black Esk catchment of the Dumfries County Council. Alkaline water is required to avoid fuel element can corrosion and pond make-up water is dosed with caustic soda to pH 11 to 11·5, a value which falls to the required running value in the pond due to carbon dioxide dissolved from the atmosphere. The water is softened in an ion-exchange softener prior to dosing, so that the caustic soda can be taken up without precipitation which would cloud the water.

Pond cleaning

About 3 pct of the contents of each half-pond will be drawn off each day, in order to keep the pH value up and assist in keeping the pond activity down and the water clear. This water is drawn off from the burst bay and flows under gravity into the 'dirty detention tank, the first of two tanks each of which is sized to hold up to two days' drawoff from each half-pond. A suction squeegee device is also provided for 'sweeping' the walls and floor of the ponds clear of solid matter which settles out, and discharges its sweepings to the dirty detention tank. The dirty tank also receives, of course, the decontamination solution bleed and the water from the coffin and basket decontamination bays. The contents of the dirty tank can be continuously circulated through one of two duplicate filters, capable of removing particles down to two microns, or pumped through the filter into the second, or 'clean' detention tank. There is also facility to pump the water back to the ponds after filtering. The filtered water is held in the clean tank and is discharged to the Solway during the two hours immediately following high water. It is also only discharged whilst cooling-tower-pond purging is being carried out, so that the decay pond effluent is considerably diluted before reaching the Solway. The effluent released is monitored before joining the cooling-tower-pond purge so that the amount of activity released to the Solway is kept within permissible limits.

The filters are periodically washed back into a drain sump. The contents of the sump, when full, are agitated to get the solid matter back into suspension and then pumped into a centrifuge from which the water passes back to the 'dirty' detention tank. The centrifuge has a removable liner which, when full, is removed, capped and shipped to Windscale in an auxiliary coffin also carried by a transport coffin transporter. Chapelcross, unlike Windscale, is not equipped to dispose of such objectionable waste materials.

All operating staff enter and leave the pond area through a change room and decontamination centre, equipped with normal personal-monitoring facilities. Activity in working areas of the plant is continuously monitored and recorded and local alarm systems are provided to indicate high activity.

TURBINE HOUSE AND CONVENTIONAL PLANT

In the interests of speed and economy the UKAEA ordered eight more turboalternators and condensing plant and four more dump condensers to the Calder designs from C. A. Parsons & Co Ltd, and, in basic layout, the turbine house is the two Calder turbine houses placed end to end with an additional bay added as loading bay and maintenance facility. There are, however, a number of other differences.

Steam pipework from the heat exchangers is of 15¼ in. nominal bore and one such pipe is used for high-pressure steam and one for low-pressure steam from each pair of heat exchangers, as at Calder. The pipes enter the rear of the turbine house just below operating floor level in two groups, with four high-pressure and four low-pressure pipes in each group. The arrangement of main steam pipework is shown in figure 8 which shows that reactors, turbines and dump condensers are arranged in a unit system. Within the turbine house the high and low-pressure steam

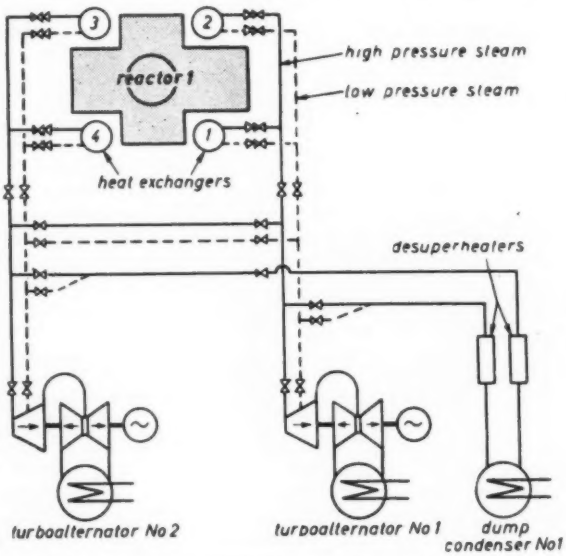

Fig 8 The steam connexions are different from those at Calder Hall. One reactor serves two turbines: there are no cross-connexions with the other sets

from each pair of heat exchangers is piped straight to a particular turbine or to a particular dump condenser. Cross-over connexions are provided so that the steam from one pair of heat exchangers can be supplied to the turbine associated with the other pair of heat exchangers of the same reactor, but there are no connexions to the turbines or dump condensers associated with other reactors. Thus reactor 1 steam goes to turboalternators 1 and 2 or to dump condenser 1 only. Steam receivers, 16 of which were installed at Calder, are not used, and there is consequently much more space available in the basement.

Feed water arrangements

The unit system is not continued in the feed and condensate systems, where common headers are used, but the feed pumps are arranged in two half-station groups. A total of six 650 klb/h main feed pumps, by Sulzer Bros (London) Ltd, are to be installed instead of the twelve smaller pumps used at Calder, but the design and arrangement of the four standby d.c.-driven feed pumps will be the same at the two stations.

Water for boiler make-up comes from the Black Esk catchment of the Dumfries County Council and is treated in a starvation/degas/mixed-bed *deminrolit* plant supplied

by the Permutit Co Ltd. The plant is built in two halves, each capable of softening 4000 gallons per hour, and its output goes on, as at Calder, to Boby make-up deaerators. Steam and feed pipework at Calder crosses from the heat exchangers to turbine houses at high level over pipe bridges, but at Chapelcross such pipework is run in open trenches. A small economic advantage was expected from this change, and it results in a tidier site. The pipes leave the trenches immediately at the rear of the turbine house and rise to enter that building just below operating floor level.

The steel frame for the turbine house was designed by W. V. Zinn & Partners and, although it is based on their design for Calder, doubling the length of the main building entailed a fundamental reappraisal of wind stresses whilst plant changes necessitated redesign of the steam and electric annexes.

Cooling water changes

The circulating water pumps have been brought into the turbine house and occupy some of the space made available in the basement by abandonment of the steam receiver layout. Four 50,000-g.p.m. pumps by W. H. Allen, Sons & Co Ltd, fully cross-connected on the discharge side, supply the whole station. Concrete culverts are used for the C.W. system, both inside the turbine house and out, instead of the steel pipes in trenches used at Calder, and this arrangement gives a load-bearing turbine house basement and avoids the embarrassment of having the floor open at a late stage of construction for laying of C.W. pipes. A 20-point chlorinating plant by Wallace & Tiernan is to be installed, injecting into each half of the set condensers, which are of split design, and into each of the single-shell dump condensers.

The cooling towers are of the same capacity and design (three million g.p.h., L. G. Mouchel & Partners Ltd) as Calder, but there are small foundation changes to suit the site. Pond make-up water, to cover evaporation and purge, is taken from the River Annan at a normal maximum rate of six million gallons per day. The water purged runs under gravity to the Solway and, as mentioned in the section on the decay pond, is used as a preliminary diluent to the decay-pond effluent.

ELECTRICAL DISTRIBUTION SYSTEM

In principle, the main electrical connexions are generally similar to those adopted at Calder but the absence of the complications introduced there by Windscale permits a simpler system. One of the generators associated with each reactor is connected straight to a 3-breaker 11 kV switchboard, one of the other two breakers supplying the reactor board through an electrical reactor and the third handling the net output to an 11/132 kV, 30 MVA transformer. The other generator of the pair feeds a similar transformer through an 11 kV breaker and the two transformers are paralleled on the 132 kV side and cabled to the 132 kV grid sub-station of the South of Scotland Electricity Supply Board. Ultimately Chapelcross will be connected at 132 kV to Dumfries by one line, to Galashiels by one line and to Harker by two lines. The reactor board is normally supplied either from one of its own turboalternators or from the grid, that is to say as directly as possible in accordance with the principle of considering reactor supplies to be of first importance. There are four turbine house boards and, as they are regarded as subsidiary to the reactor supplies, each is fed from its associated reactor board. Reactor boards 1 and 2 can be interconnected and so can reactor boards 3 and 4, but the electrical system of the whole station is in two halves at 11 kV.

The electrical annexe has been completely redesigned. The 11 kV switchgear associated with each pair of turboalternators is situated adjacent to them in the annexe, between the electrical reactor and the turbine house transformer and other service transformers. The generator transformer compound runs parallel to the electrical annexe with an access road between the two. By this layout the 11 kV cabling is kept short and the total cost of 11 kV and 132 kV cabling kept to a minimum.

As the station was planned from the outset as a 4-reactor station only one electrical control room is, of course, provided, from which the eight turboalternators are controlled and 11 kV and 132 kV switching carried out.

CONSTRUCTIONAL METHODS

Construction work at Chapelcross is perhaps chiefly remarkable for the fact that the four reactors are being built simultaneously and are timed to be completed at four-monthly intervals. Construction periods for the reactors are shown on figure 9, which also shows construction periods for Calder. For all reactors, tests to prove plant items individually and to check reactor circuits as a whole are carried out by the construction staff

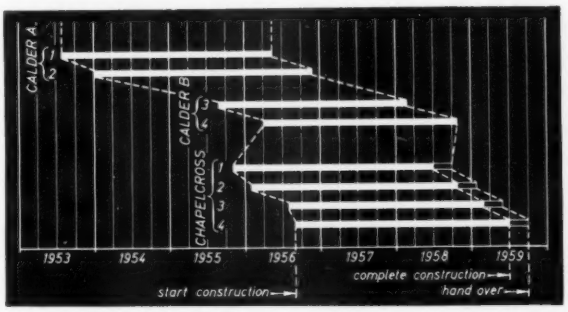

Fig 9 Bar chart shows construction schedule for both Calder Hall and Chapelcross

upon completion of erection and before the plant is handed over to Operations Branch for final commissioning. At Chapelcross it is planned to finish construction of each reactor three months before hand-over and to use those three months for the tests.

To achieve such a concentration of effort the Consultants have built up a large site organization which enables engineers to specialize on particular sections of construction. Materials are progressed partly by a group at Head Office and partly by a group at site, both of which are directed by engineers. The site group also carries out inspection on delivery and deals with the problem of disseminating information to the large site staff: their task is to see that the right information and materials are in the right hands at the right time.

Site arrangements

Preliminary work on site began in July 1955 and was largely concerned with the rehabilitation of airfield buildings, which were nearly sufficient to meet all construction needs.

The main runway was 150 ft wide and it is interesting to record that, not being reinforced, it soon broke up under construction traffic. However, it provided a useful basis for temporary construction roads and a large area of it has been most useful for outdoor storage of plant. A permanent road now runs along its northern edge and is part of the system of the permanent roads, giving access to all parts of the Works, which was completed at an early date to facilitate construction.

A portion of the main runway, beyond the fourth reactor, was set aside as hard standing for pressure vessel fabrication. A 28 ft gauge rail track was laid down the centre of the runway, from that area past the reactors, along which the pressure vessel sections are transported. Tracks were laid down either side of the reactor line, spanning the construction road on the north and the permanent road on the south, and three 10-ton and one 5-ton derricks, each with 120 ft jib and mounted on 45 ft gabbards, run on those tracks on each side of the reactors. The gabbards are high enough to clear all normal construction loads but their lower braces are removable to permit the passage of heat exchangers beneath them. It is here that the in-line arrangement of the reactors shows to special advantage for the derricks can be very readily

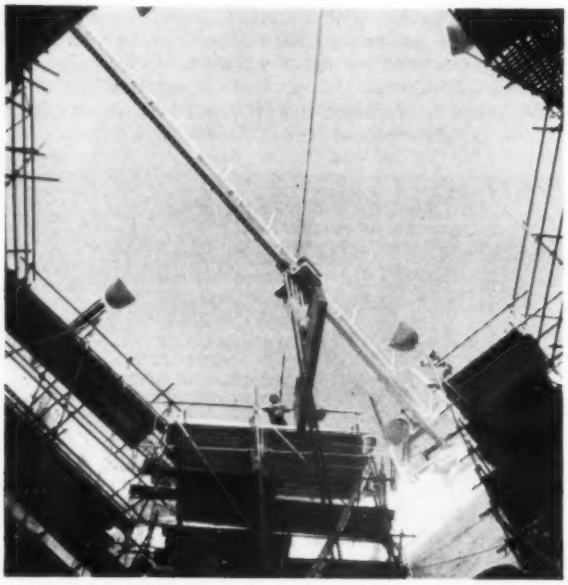

Fig 10 Inside the biological shield, thermal shield plates are manœuvred on a travelling hoist. This method halved the time taken at Calder for this job

traversed from reactor to reactor and concentrated to meet day to day requirements. The derricks were provided by the general civil contractor primarily for the use of the plant contractors.

Contract to open tender

Early erection experience at Calder was available when Chapelcross was started. Some of it had been obtained directly by the nucleus of the Chapelcross erection staff, who were thus able to build their erection techniques on what they knew to be sound from Calder.

In contrast to Calder Hall, the general civil work at Chapelcross is covered by a scheduled-rate contract which was put out to open tender. It was placed with the Mitchell Construction Company, in October 1955.

All the aggregate used in concrete throughout the site, except for the biological shields, has been obtained from a quarry opened locally by the Mitchell Construction Co. Further, the dry density of 150 lb/ft^3 specified for the biological shields has been obtained with a mixture of 75 pct local and 25 pct Whinstone aggregate, compared with the 100 pct Whinstone aggregate used at Calder. The Mitchell Construction Co have also been able to undertake all concrete work except the cooling towers with one batching plant only, by using that plant exclusively for batching and completing the mixing in truck mixers.

Time-saving methods

In the construction of the biological shield use was made of prefabricated climbing-shuttering panels, with screw adjustment for verticality, instead of the rigid steel framework employed at Calder. Not only did this save the time required to strike the framework but it also permitted the vertical support pillars for the thermal shield to be erected at the same time as the biological shield. For the erection of the side thermal shield a steel runway, constructed on site, was rested on the biological shield, spanning the reactor chamber, and adjusted in position to suit the face being erected: the shield plates were lifted into place using a 5-ton hoist travelling on the runway. By these innovations the erection time on the thermal shield was cut by half.

Pressure vessel fabrication takes place on the edge of the old main runway and temporary sheds are provided over the more important parts. Experience has suggested that in future all fabrication should take place under cover because high-quality welding is more easily obtained under good working conditions. After each section of the vessel is completed it is carried on a special bogie over the 28 ft-gauge track to the vicinity of the reactor discharge face, and handled into the octagon from there by a guyed derrick. The derrick used at Chapelcross has a 105 ft jib and is used for a maximum load of 100 tons at 60 ft radius. It is mounted on the biological shield, over the discharge well, not on the steel tower as used at Calder, and is moved from reactor to reactor after main pressure-vessel and certain ancillary lifts are completed.

Pressure vessel cleaning

After stress relief and pressure testing of a completed pressure vessel it has to be most thoroughly cleaned internally before graphite laying can begin. The area to be cleaned is about 10,000 sq ft, including the graphite support grid, and the method to be used was carefully considered before shot blasting was chosen. The work was entrusted to F. W. Berk & Co Ltd, who employ three Schori open-blast plants mounted inside the vessel, together with a system of platforms to facilitate shot recovery. A downward draught of air through the vessel is induced during shot blasting, which is done only at night. During the day the freshly cleaned surfaces are inspected and, if satisfactory, are *dagged*.

The hangar adapted for heat exchanger fabrication is large enough to permit work to be carried out on four heat exchanger shells simultaneously. The shells arrive on site in ring sections and Babcock & Wilcox continue to use their now-well-proved methods of fabrication. The interior of the shells are shot blasted by the *Vacu-Blast* method, which gives a better finish than is obtainable by hand. When completed the shells are taken by a special low-loader over site roads to the reactors and lifted by two gin poles, as at Calder. All sixteen shells have been completed and twelve are already erected.

Although little progress in design has, perforce, been possible at Chapelcross, there have been improvements in construction technique and construction experience has been spread to a large number of engineers. In due course there will be a similar increase in experienced plant operators, all of whom will help to strengthen the nuclear energy industry in this country.

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INDUSTRY'S CONTRIBUTION

In the construction of the new station many hundreds of British firms were involved, not all of which had been engaged at Calder Hall. Here are details of some of these contributions

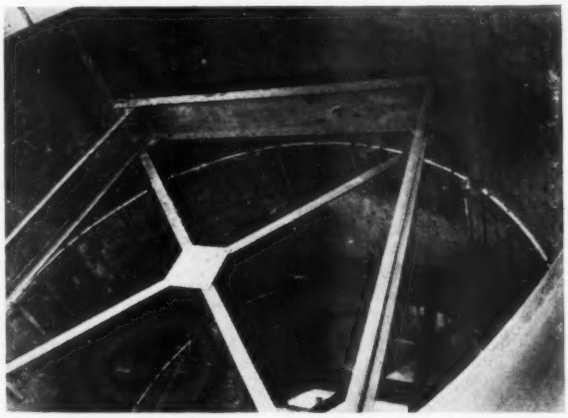
Steam-raising equipment

Steam from each of the four reactors is raised in four heat-exchangers or boilers. Built by Babcock & Wilcox Ltd to the well-tried Calder design, these shells are 18 ft dia. and 70 ft high, 1-5/16 in. plate. Each boiler contains economizer, evaporator and superheater sections for both h.p. and l.p. steam. Except for the superheater pipe sections, which are plain, the tube banks are provided with extended surface in the form of welded elliptical studs. The boilers arrive at the site in cylindrical sections which are then welded together and the completed, empty shells raised onto their plinths. After this, the tube banks are installed, precautions being taken by means of air locks to ensure perfectly clean conditions inside.

In addition to the heat exchanger equipment Babcocks have also supplied a number of cranes for the spent-fuel handling plant at Chapelcross. These comprise: a 50-ton O.E.T. 2-motor crane for handling transport coffins; one 1-ton O.E.T. crane for lifting empty baskets in the decontamination bay; two 1,600-lb travelling platforms with hydraulic hoist and travelling motor for lifting baskets out of the flasks; two 3½-ton Goliath cranes (5-motor type) for transferring skips between the transfer and exit bays and the main ponds and burst cartridge pond; one 7½-ton O.E.T. hoist for lifting the general purpose flask from the road vehicle to the burst slug bay.

Heat-exchanger stress relieving

Induction heating plant was supplied by the Electric Furnace Co Ltd to Babcock & Wilcox for stress relieving on site welds in the heat exchangers. Medium-frequency



Induction heating elements installed inside a heat-exchanger

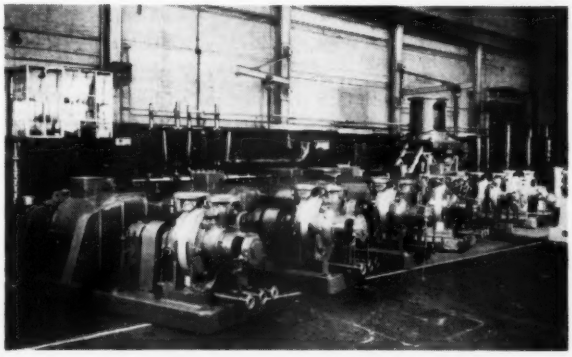
current obtained from a motor-alternator frequency-converter has the advantage over normal mains frequency current in that much fewer number of turns of inductor cable is required, thus considerably simplifying the handling of the cables. There is the added advantage of the greater degree of control provided by the adjustment of the alternator field.

Supplies are obtained from a vertical water-cooled motor-alternator, the alternator being rated at 200 kW, 2,500 cps. The alternator current is taken to a heater station containing the power factor correction capacitors, and from here, busbars are taken by under-floor ducts to a number of distribution points.

The cables, four on either side of the weld, are laid over the vessel, which is mounted on rollers to facilitate welding. The cables are laid on heat insulating material and are enclosed in metallic covers containing additional insulation. Insulation is also placed inside the vessel underneath the weld and retained in position by covers.

Boiler feed pumps

The boiler feed pumps are by Sulzer Bros. (London) Ltd. manufactured at their Leeds Works. These pumps are of the multi-stage high efficiency centrifugal type designed



These six Sulzer pumps supply boiler make up

with stable characteristics for a duty quantity of 650 k lb/h and pressure up to 355 psi, the feed water being at a relatively low temperature.

The pumps are of the sectional casing foot mounted type instead of whole casing central line mounting as adapted for high temperature conditions. The six sets of pumps are direct coupled through flexible couplings to 380 bhp squirrel cage motors running at 2960 rpm each set being mounted on combined base plates.

High-voltage switchgear

At Chapelcross, Reyrolle type-B5T 11-kV 500-MVA metalclad switchgear is being supplied to control eight 28,750-kVA continuous-maximum-rated generators, eight 132/11-kv 30-MVA SSEB Grid Transformers and four 30-MVA reactor-pile feeders.

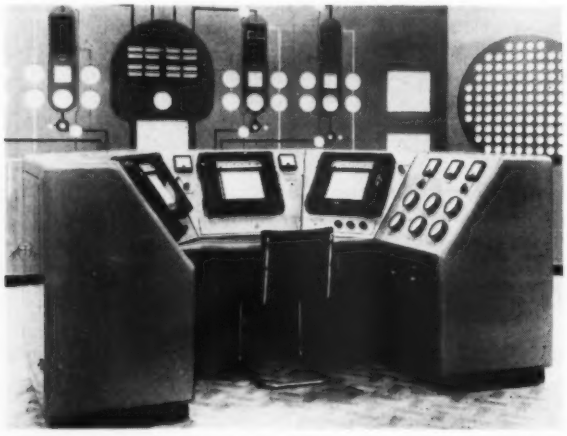
In the main control room Reyrolle are supplying a centre-section corridor-type control and relay board for the main 11-kV switchgear, complete with eight generator A.V.R. cubicles. Two draught synchronizing frames for the 11-kV main switchgear, the 11-kV Pile House switch-

gear, and the 3·3-kV Turbine House switchgear are also included on this main control-board.

The three station batteries were supplied by The Tudor Accumulator Co Ltd on sub-contract. The main 240-volt closing battery is of 800 ampere hour rating, and is equipped with a Hackbridge and Hewittic charger/distribution board incorporating two full-wave mercury-arc rectifiers.

Reactor control rooms

As at Calder Hall 'A' and 'B', New Western (Engineering) Limited were commissioned by the AEA to provide and instal the control rooms for Chapelcross. The



Non-reflecting finish gives excellent visibility of graphic panel

design and instrumentation was engineered by the Authority and the task of the contractors was to carry out this work and present it in a pleasing yet functional form.

In addition to the Control Room panelling, Control Room desk, and other furniture, New Western have been entrusted with the installation of all instruments, both in the control rooms and on the site, together with all necessary wiring and pipework. The testing and commissioning, prior to the plant being handed over to the operating staff, will also be carried out by the same contractors.

Burst cartridge system

Initial tests on the nuclear performance of the burst slug equipment installed by Plessey Nucleonics Ltd at Calder Hall have shown that the equipment has fully justified theoretical predictions. The original background signals were found to be excessive, but suitable modifications to the purge system resulted in a satisfactory reduction.

The early precipitators incorporated case bodies of high-grade iron but the incidence of porous castings became so troublesome that it was decided to convert to a fabricated steel body.

Various other components such as motor brakes, contactors, switches, shaft seals, etc., did not give as long a working life as expected and these have now been changed or re-designed with the result that considerable improvements have been obtained in trouble-free operation.

In the early equipment, one particularly troublesome feature was the short working life of the wire in the precipitators. The majority of the wire fractures have taken place at the wire joint, so a detailed study has been made of the various forms of joint which could be used (*e.g.* crimped tube, knots, brazing, welding, splicing, etc.). Further investigations have taken place to consider the effects of wire tension, friction in pulley bearings, pulley wheel design and method of driving. Due to a tight production programme, radical changes have not been possible, but the introduction of certain features arising from the above investigations has resulted in a significant improvement in the wire life.

Most of the above improvements have also been incorporated in the later Calder reactors and operational experience so far has shown that the steps taken have been fully justified.

Effluent drain

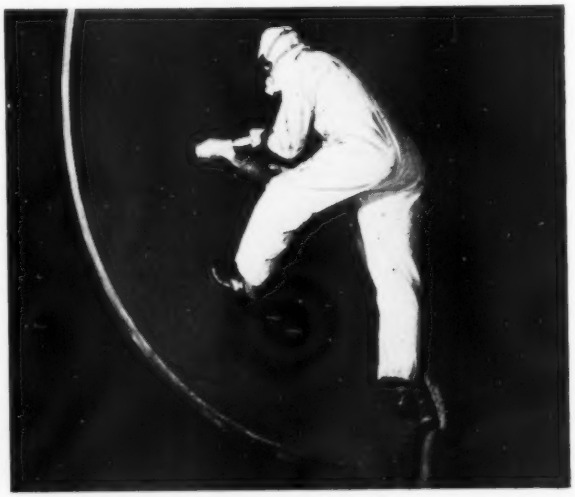
Work carried out by Tarslag Ltd comprised the laying of some 3 miles of 21 in. dia. concrete pressure pipe and included pre-cast concrete piled outfall into the Solway. In addition, the contract included approximately one mile of 24 in. cast-iron water main with Victualic joints.

Fuel charging

Changes of fuel rods at Chapelcross are carried out by means of special machines developed by Strachan & Henshaw Ltd for Calder Hall. There are two types of machine—one for charging and the other for discharging—and two of each run on rails on each pile cap. The two types of machine are basically similar but the discharge machine is heavily shielded and equipped with a built-in CO_2 cooling system, since, of course, the elements handled are highly active. Fuel elements are contained in 'baskets,' each containing 24, and each machine holds one basket. After depressurizing the pile, the relevant charge tube is connected to a discharge machine and the spent elements hoisted up into the basket by means of a flexible cable with an automatic grab at the lower end. When a channel has been discharged, a charge machine is connected to the standpipe and the new elements lowered one by one.

Boiler cleaning

The earlier heat exchangers at Calder Hall were cleaned internally by rotary wire brush but this was found unsatisfactory and a system of grit blasting developed by Vacu-Blast Ltd was chosen for Chapelcross. Owing to the interruption of the surface by structural members and thermal



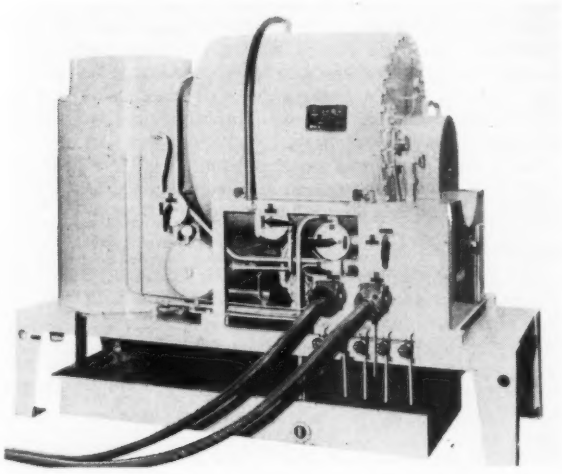
In addition to flat surfaces the Vacu-Blast gun can clean awkward corners

sleeves it is impossible to keep the Vacu-Blast gun in true surface contact so a new technique of 'open Vacu-Blast' was conceived. In this, the gun is held a few inches from

the surface and although this allows the heavy scale to fall away it continues to remove dust. The method is considered a compromise between the normal Vacu-Blast closed circuit blast and the open blast systems and has proved very satisfactory in practice. Three special Mk II Major machines are in use at Chapelcross and these give 30 minutes blasting before the abrasive is exhausted. At the end of the blast cycle the abrasive which has spilled is recovered by the vacuum hose and filtered in the machine to make it ready for the next cycle.

Transformer oil cleaning

A self-contained plant complete with its own dehydration and filter chamber, through which insulating oil used



The unit filters the oil and returns it to the transformer or breaker

in the transformers and switchgear can be circulated is being supplied by Stream-Line Filters Ltd. A single passage through the filter ensures that the oil is upgraded to a dielectric strength well above that specified for a new oil. The model supplied has full CEGB approval.

Pressure vessels

The reactor pressure vessel, by Whessoe Ltd, is 37 ft dia. by 70 ft overall height, fusion welded from 2 in. *Lowtem* high-notch-ductility, fully-killed steel plate. For a working pressure of 100 psig, design stress was 12,000 psi at 725°F with a joint factor of 0.95, necessitating full radiography of all butt welds and complete stress relief. The vessel consists of five strakes and top and bottom domes of semi-ellipsoidal form and these were fabricated on the site and assembled inside the shield.

Standby diesel generators

Eight Crossley 500 kW diesel engined automatic standby generator sets are installed at Chapelcross. There are four separate engine-rooms, one per reactor, each housing two sets. All sets are arranged to be speedily available in a condition capable of accepting loads in the event of an emergency; they are fitted with electro-pneumatic starting gear, which automatically puts the engines into action on failure of the mains supply.

Physical instrumentation

Instrumentation supplied by George Kent Ltd is very similar to that provided by them for Calder Hall. This included the physical instrumentation for high- and low-pressure steam flow; CO_2 make-up flow; high-pressure and low-pressure steam and CO_2 pressure; coolant-gas temperature; fuel-element temperature; graphite temperature; dissolved oxygen; CO_2 content in low-pressure steam; water vapour in CO_2 and high-pressure-steam and low-pressure-steam drum level. In addition, nucleonic recorders were supplied for power level drift, linear and logarithmic power level, and flux scanning. Flow differential-pressure producers of the orifice type were also provided.

Turbogenerators and gas blowers

The Calder-type turbines installed at Chapelcross by C. A. Parsons are two-cylinder machines comprising a single-flow h.p. unit solidly coupled to a doubleflow l.p. machine. Blading is all-reaction throughout. High-pressure steam (185 psig and 590°F) enters the h.p. casing and is joined after the 15th stage by l.p. steam at 38 psig, 340°F. Seven more stages follow in the h.p. casing before the steam is transferred to the l.p. cylinder. Each of the eight sets is fitted with surface condensers of normal Parsons design and the turbine house is also fitted with four dump condensers for use when starting or when the demand falls short of the output. The direct-coupled Parsons generators have a CMR of 23MW and operate at 3,000 rpm, 11.5 kV, 0.8 power factor.

The main gas circulators by Parsons are of the centrifugal pattern with horizontal spindle and the four for each reactor handle between them a normal mass flow of 1,964 lb/sec of carbon dioxide. The blowers are driven by separately excited compound-wound d.c. motors by Mather & Platt Ltd. These are designed for speed regulation on the Ward Leonard principle by variation of the armature voltage over a range of 10:1. Control boards are by Whipp & Bourne Ltd.

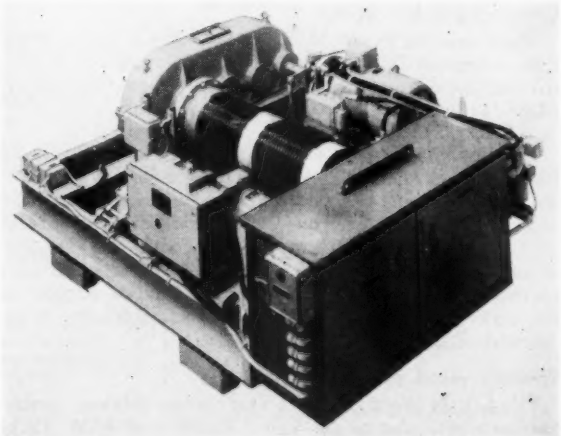
Parsons were also responsible for the gas ductwork and bellows expansion joints.

Carbon dioxide plant

The Chemical Division of The Distillers Company Limited, has provided the liquid carbon dioxide bulk storage and evaporation equipment for the new station. The installation includes five thermally-insulated bulk storage tanks, each with a capacity of 20 tons of liquid CO_2 and with a pressure-operated refrigerator and safety valves, together with six evaporators, each capable of vaporizing 3 ton of CO_2 per hour.

Turbine Hall and Blower House cranes

Wharton Crane & Hoist Co Ltd have installed, or are installing, seven overhead travelling cranes, details of which are as follows:



This 20-ton crab has contactor switchgear for pendant push-button operation

One 60-ton, 4-motor, O.E.T. crane, span 78 ft, in the main turbine hall. The primary duty of this crane is for installation and maintenance of essential equipment.

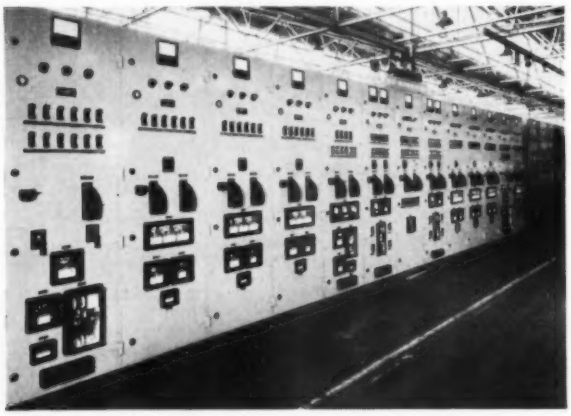
To meet the demands of the varied lifts, in addition to the main hoist of 60 tons capacity, at a speed of 5 fpm, a change speed gear is fitted to lift 25 tons, at 10 fpm. Additionally an auxiliary hoist of 12 tons capacity at 35 fpm is also incorporated, thereby ensuring quicker handling of light loads.

Six 20-ton, 4-motor, O.E.T. cranes, span 56 ft 4 in., are located in the long and short blower houses, for Nos. 1 and 2 Reactors, the main hoisting speed being 15 fpm.

Auxiliary switchgear

The English Electric contribution to Chapelcross consists of auxiliary control switchgear, the details of which are as follows:

Four 13 panel 415 volt OB3 airbreak switchboards. These circuit breakers control auxiliaries associated with reactor No. 4: Two 13 panel OB33 3,300 V airbreak switchboards. These breakers control auxiliaries associated with



A 13-panel 415 V air-break switchboard

the turbo-alternators in the power house: Four 14 panel OB33 3,300 volt airbreak switchboards. The duties of these panels are the same as for the 13 panel OB33's: Four 350 MVA, 11 kV switchboards each incorporating 5 OLE and 8 OLD metalclad circuit breakers. These switchboards are double busbar units with on-load selection. Their duties are the control of reactors Nos. 1, 2, 3 and 4 and each supplies MG sets and transformers.

Circulating water pumps

Plant supplied by W. H. Allen Sons & Co Ltd of Bedford, comprises four 48/48-inch vertical double-action centrifugal circulating-water pumps, each designed to deliver 50,000 gallons of water per minute against a total head of 67 feet when running at a speed of 490 rpm.

Each pump is driven by a 1225-h.p. Laurence Scott & Electromotors vertical, squirrel-cage, totally-enclosed motor, provided with closed-circuit water-cooled air cooler. The motors are mounted on the pumps to which they are directly connected by means of a flexible coupling of the pin-and-bush type. The pump shaft rotates in one combined thrust-and-journal bearing, arranged outside at the top of the pump, and a grease-lubricated bearing fitted internally at the base of the pump.

Pressure vessel shot-blasting

The task of shotblasting the four reactor pressure vessels has been entrusted to the Schori Division of F. W. Berk & Co Ltd. Shotblasting was carried out on night-shift using one foreman, four shotblasters, four labourers and one compressor attendant. Work commenced on the dome, which included the internal surfaces of charge tubes, etc., and then proceeded in regular levels downwards to the bottom barrel. At the end of each shift, all loose shot was cleaned from the scaffold and collected and bagged on the working platform below.

The complete pressure vessels have an internal surface area of approximately 18,000 sq ft. The first vessels were completed in 17 night shifts, giving an average of slightly over 1,000 sq ft blasted per night. Actual blasting speeds varied widely depending on the type of work. On large flat areas, for instance, some operators achieved a speed of 140 sq ft per hour whilst in the very restricted sections, it was as low as 10 sq ft per hour.

Boiler circulation pumps

Hayward Tyler & Co Ltd have supplied a total of 34 glandless circulating pumps. Sixteen of these pumps will operate the low pressure secondary circulating systems at 108 psig and 16 will operate the high pressure secondary circulating systems at 270 psig. The remaining two pumps are supplied as stand-by units.

Since both pump and motor are contained in a pressure shell, leakage to atmosphere is effectively prevented. No rotating seals of any kind are employed.

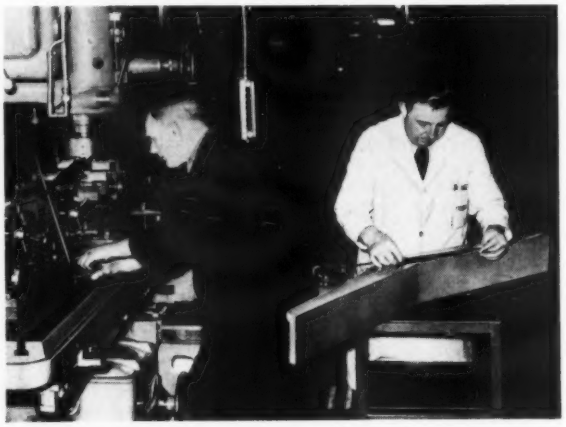
Air filters

Air filtration equipment supplied by Heather Filter Ltd, comprises standard 24 by 24 by 2¼ inch units with galvanized after-manufacture finish. They are used for removing impurities from the air supplied to the reactor blower motors and motor generator sets.

The four reactors each have four banks of air filters, each consisting of 90 units capable of handling 65,000 cfm.

Reactor details

Equipment supplied by Chatwood-Milner Ltd includes: periscope shields, liner plug tubes, ion chamber liner tubes,



Graphite restraint beams are manufactured at Chatwood-Milner's Shrewsbury works

concrete-filled plugs for viewing gear, various details for ion chamber thermal column, graphite installation set, graphite restraint equipment (restraint tie bars and beams), irradiation tube plugs, lead-lined doors, shield bridge assembly, flux scanner shield plugs and guide tubes.

Lighting system

Because of the size of the Turbine Hall Control Room (approx. 3,000 sq ft) and the arrangement of the control panels, lighting—by A.E.I. Lamp and Lighting Co Ltd—

has been considered under three main headings: 25 to 30 lumens per sq ft in the central working area; 20 to 25 on the vertical faces of the control panels; 15 in the corridor area surrounding the control panels.

Special lighting has also been installed in the four reactor control rooms. This lighting scheme is similar to the scheme designed by A.E.I. for Calder Hall, where continuous rows of bare lamp fluorescent fittings are mounted above a luminous ceiling of opaque Perspex panels.

Pipe and tank insulation

The thermal insulation of pipe lines and tanks at Chapelcross makes extensive use of Versil glass fibre. This material is applied to the specified thicknesses chiefly in the form of flexible sections, blankets and loose fills in one or more layers. On internal pipes the insulation is finished with *Versilex* cold-setting, quick-drying cement, reinforced and trowelled to a smooth hard surface. On external pipes the insulation is enclosed in bitumen felt, finished with *Alocromer* aluminium cladding. The extent of the work consists of the high and low pressure steam mains and auxiliary steam piping and feed, drain and damp steam piping within and external to the Turbine Hall, together with the surge tanks.

CHAPELCROSS CONTRACTORS

The Consulting Engineers and Architects to the United Kingdom Atomic Energy Authority are MERZ & MCLELLAN *and* L. J. COUVES AND PARTNERS *respectively. Contractors included:*

ACCLES & POLLOCK LTD
Stainless steel tubing

A.E.I. LAMP AND LIGHTING CO LTD
Light fittings—turbine hall control room

W. H. ALLEN, SONS & CO LTD
Main circulating water pumps

APPLEBY & IRELAND LTD
Control rod indicators

ARMSTRONG WHITWORTH (METAL IND) LTD
Pressure vessel shield plugs and wall seal assemblies

BABCOCK & WILCOX LTD
Heat exchangers, cartridge cooling pond equipment

SIR W. H. BAILEY & CO LTD
Low pressure C.W. valves

WILLIAM BEARDMORE & CO LTD
Steel plate for thermal shield

F. W. BERK & CO LTD (SCHORI DIVISION)
Shot blasting of pressure vessels

J. BLAKEBOROUGH & SONS LTD
Gas valves and control gear

WILLIAM BOBY & CO LTD
Two make-up deaerators

JOHN BOYD & CO (ENGINEERS) LTD
15-ton O.E.T. crane

BRITISH ACHESON ELECTRODES LTD
Moderator graphite

BROOKHIRST SWITCHGEAR LTD
Motor starters and panels

BROOM & WADE LTD
Diesel-driven air compressors

BURNDEN PARK ENGINEERING CO LTD
Charge pan components

BURNETT & LEWIS LTD
Gas drying plant

W. P. BUTTERFIELD LTD
Irradiation hood tubes and liners

BUTTERS BROS & CO LTD
Derricks

THE CARBON DIOXIDE CO LTD
Carbon dioxide

CHATWOOD-MILNER LTD
Reactor components

COLVILLES LTD
Reinforcing bars

CONSETT IRON CO LTD
Mild steel plates

CONTACTOR SWITCHGEAR LTD
Auxiliary contactor starters

WILLIAM COOKE & CO LTD
Thermocouple and lifting cable

CRAVENS LTD
Shield plugs and spent fuel skips

CROSSLEY BROTHERS LTD
Standby diesel generating sets

THE DARLINGTON INSULATION CO LTD
Reactor thermal insulation

DARLINGTON FENCING CO LTD
Site fencing

DELAPENA & SON LTD
Induction heating equipment

DEWRANCE & CO LTD
Mountings and valves

DICKS ASBESTOS & INSULATING CO LTD
Gas plant insulation

THE DISTILLERS COMPANY LTD
Gas storage and evaporation plant

DISTINGTON ENGINEERING CO LTD
Sh.e.d cooling stacks and three transport coffins

THE ELECTRIC FURNACE CO LTD
Heat exchanger stress-relieving equipment

ELLIOTT BROS (LONDON) LTD
BSD gear, recorders, transmitter gauges etc.

JAMES W. ELLIS & CO LTD
Steelwork

ENGLISH ELECTRIC CO LTD
Auxiliary switchgear and control equipment

ENGLISH STEEL FORGE AND ENG LTD
Steel plate for thermal shield

E.R.F. LTD
Transport vehicles for coffins

ERICSSON TELEPHONES LTD
P.A.B.X. telephone equipment

EVANS LIFTS LTD
Lifts in reactor buildings

FAIREY AVIATION CO LTD
Graphite restraint equipment

FILM COOLING TOWERS (1925) LTD
Water coolers for auxiliary circuits

ALEXANDER FINDLAY & CO LTD
Structural steelwork

HACKBRIDGE & HEWITTIC ELEC CO LTD
11·5kV reactors

HADFIELDS LTD
Control and shut-off rods

HAM, BAKER & CO LTD
Pen locks and sluice valves

HAYWARDS LTD
Lantern lights and steel doors

HEATHER FILTERS LTD
Air filters

HENRY HARGREAVES & SONS LTD
Ducting

W. T. HENLEY'S TELEGRAPH WKS CO LTD
11kV and l.v. cables and accessories

JAMES HOWDEN & CO LTD
Shield cooling fans

IMPERIAL CHEMICAL INDUSTRIES LTD
Stainless steel pipework for BSD gear

R. JENKINS & CO LTD
Mild steel ductwork

GEORGE KENT LTD
Recorders and instruments

THE WALTER KIDDE CO LTD
Fire alarms and automatic extinguishers

JAMES KILPATRICK & SON LTD
Lighting, heating and plug point installation

RICHARD KLINGER LTD
Cocks for burst cartridge detection gear

MAGNESIUM ELEKTRON LTD
Fuel can material

MATHER & PLATT LTD
Gas circulator motors, fire fighting installation

THE MITCHELL CONSTRUCTION CO LTD
Main civil contractors

METROPOLITAN-VICKERS ELEC CO LTD
Frequency converter and control rod actuators

MUNRO & MILLER LTD
Two oil-storage tanks

NEWALLS INSULATION CO LTD
Thermal insulation

NEWBURGH ENGINEERING CO LTD
Charge pans and fuel element strut assemblies

NEWMAN HENDER LTD
Gas plant valves

NEW WESTERN ENGINEERING LTD
Instrument installation and commissioning

NORTHUMBERLAND WHINSTONE CO LTD
Supply and delivery of aggregates

PANTAK LTD
Radiography equipment

C. A. PARSONS & CO LTD
Gas circulators, ductwork, generating plant

THE PERMUTIT CO LTD
Water treatment plant

PLESSEY NUCLEONICS LTD
Burst cartridge detection gear

POLLARD BEARINGS LTD
Graphite support bearings

PYROTENAX LTD
Thermocouplings

THE REDHEUGH IRON & STEEL CO
Two horizontal oil-storage tanks

A. REYROLLE & CO LTD
11·5kV switchgear, l.v. distribution

RUBERY OWEN & CO LTD
Liner tubes

SANDALL PRECISION CO LTD
Control rod details, fuel struts

JAMES SCOTT & CO LTD
Electrical construction supplies

SIEMENS BROS LTD
Cable racking

SIMMS, SONS & COOKE LTD
Dormitories, bungalows, kitchens etc

STANDARD TELEPHONES & CABLES LTD
Operational telephones

THE STANTON IRONWORKS
C.I. special pipes and Victaulic joints

STEELS ENGINEERING PRODUCTS LTD
20-ton lorry-mounted mobile crane

STEWARTS AND LLOYDS LTD
H.P. and L.P. piping and valves

R. B. STIRLING & CO LTD
Ductwork

A. A. STUART & SONS (GLASGOW) LTD
Admin. building and police lodge

STRACHAN & HENSHAW LTD
Reactor fuelling machines

SULZER BROS (LONDON) LTD
Six boiler feed pumps

TARSLAG LTD
Effluent drain to Solway

TAYLOR WOODROW CONSTRUCTION LTD
Preliminary works

TRANSFORMERS (WATFORD) LTD
415/110V transformers

DAVID THOMPSON & SONS LTD
Heating services, control building

JOHN THOMPSON LTD
CO_2 storage tanks

VACU-BLAST LTD
Shot blasting equipment for heat exchangers

VERSIL LTD
Heat insulation of pipework etc

VOKES GENSPRING LTD
Pipe supports

THE VULCAN FOUNDRY LTD
Flux scanning gear

WAKEFIELD-DICK INDUSTRIAL OILS LTD
Lubrication

WALLACE & TIERNAN LTD
Chlorinating plant

T. W. WARD LTD
Installation of graphite, machinery etc

G. & J. WEIR LTD
Feed water regulators

JAMES M. WELLS & CO LTD
Workshops and stores buildings

THE WHARTON CRANE & HOIST CO LTD
O.E.T. cranes

F. H. WHEELER (SCOTLAND) LTD
Electrical installation of main admin. block etc

WHESSOE LTD
Pressure vessels

WHIPP & BOURNE LTD
Rectifier switchboards and Ward-Leonard control

WIDNES FOUNDRY & ENG CO LTD
Cast-iron coffins

YORKSHIRE ELEC TRANSFORMER CO LTD
11·0kV and l.v. transformers

REACTOR TEST LOOPS

2. Design factors

by A. T. HOOPER, M.A. (Cantab)

Project Engineer, Reactor Services Group, AERE, Harwell

Following last month's introduction to this series, this article describes the general procedure for the design of a major loop in DIDO *and* PLUTO *and some problems of particular types now built or building. Major loops are chosen because they represent the most complex design problem, involving nearly all the limitations met in other in-pile equipment. The approach described is directly applicable to hot loops for* DIDO *and* PLUTO *but may be adapted for other loops.*

A LOOP IS BUILT to provide information for a reactor project team. The team draws up a specification for the loop which should be as detailed as possible. About two years may elapse between the beginning of design and the end of commissioning in which time the ideas of the project inevitably alter. In consequence the loop design must be kept as flexible as practicable to allow the incorporation of as many of these new requirements as possible and also to enable it to be modified in the light of commissioning experience. It should also be noted that the specification should be written as late as possible, since changes tend to be less numerous and less drastic as time goes on. It is evident that the closest liaison must be maintained between the loop design and the project, since the project is the focus of the efforts of many specialist branches and the results of their work, even if not incorporated in the loop, may provide valuable background information.

DESIGN PROBLEMS

The project's specification forms the basis for a feasibility study with the object of ensuring that

sufficient flux is available in the research reactor
the safety of the research reactor is not prejudiced
the requirements can be met in the space available in the experimental hole around the research reactor.

This is followed by design studies to determine the best method of tackling the problem. There is not at present sufficient experience available to avoid this stage and even successive loops for a given project have each to be considered afresh. One reason for this is that a loop design is limited not only by the requirements of the project for which it is being made but also by the requirements of the research reactor in which it is to run. There are obvious difficulties in putting a high temperature loop in an experimental hole in DIDO or PLUTO in which the heavy water moderator operates at 70°C. It is found that every loop has a particular design problem which predominates over all the others, its exact nature depending on the coolant used and the information being sought. Thus, in an organic liquid loop, polymerization of the coolant might be the predominating problem.

The design studies should be carried far enough to show that a design solution is possible and this often entails a considerable amount of detail work. The problems to which design solutions must be found can be divided into the following headings:

1. Maximum safety

A loop may present problems of safety:

a. as a pressure vessel
b. as a source of radiation
c. as a source of toxic or radioactive leakage.

Loops have a shorter running life than a research reactor and tend to be thought of as experimental rather than plant equipment. Care must nevertheless be taken to make a loop as safe as the reactor in which it runs, being capable of withstanding the most severe conditions which the reactor itself can survive. This may impose on the loop far more rigorous conditions than those of its nominal design point at the rated output of the reactor.

As a pressure vessel a loop has two dangers in addition to those generally found in industry. Firstly the products liable to be released are often more hazardous and difficult to clean up. Secondly, damage to the reactor following a loop rupture could endanger health and put the whole reactor out of commission for months. For these reasons the closest attention is paid to the design of the pressure vessel and the highest standards of workmanship and inspection are required. BS 1500 is used as far as possible but there may frequently be cases for which this code is unsuitable. The in-pile pressure vessel mentioned below is a typical example which could not follow this standard since an unacceptable weight of steel would be involved. Temperature conditions are met with which are outside the scope of BS 1500, but effort is always made to base designs on the best existing relevant practice, the ultimate object being to draw up a code of practice for this class of work. Since the consequences of rupture are so serious, loops are customarily fitted with a bursting disk venting to a dump tank and set to function at a pressure above that at which the loop trips operate.

As a source of radiation hazard the loop may reduce the efficiency of the reactor biological shielding in the experimental hole and permit the escape of some reactor radiations from the reactor core. In the event of the loop coolant carrying fission products or becoming active under irradiation the out-of-pile sections of the loop will also have to be shielded. Consideration must also be given to the increase of activity in the coolant due to a leaking fuel can.

As a source of leaks the degree of hazard depends on the nature of the coolant. In the case of a particular high temperature gas loop the smallest leakage which can be detected in the inactive state might present a health problem in the operational state and it has been found necessary to enclose the pressure loop in two further complete containment shells.

2. Maximum reliability

Research reactors represent a high capital investment and must be kept running. An unreliable loop which causes a reactor to shut down is also holding up all other experiments in the reactor as well as loss of isotope irradiation time. With this in mind, mechanisms inside the loop vessels are avoided wherever possible and if they cannot be avoided are kept as simple and robust as possible.

3. Nuclear effects

The minimum of neutron absorbing material must be used in the reactor experimental tube in the region where it passes through the moderator and reflector since it will screen the experimental fuel element from neutrons and increase the local flux depression caused by the fuel. (This effect is most marked in high flux holes in DIDO and PLUTO.) In this zone of the reactor any material will generate heat due to neutron, gamma and beta bombardment. The rate of heat generation is very approximately $\frac{1}{4}$ kW per pound of material, and its dissipation may well present a problem. The conflicting requirements of these effects and pressure vessel safety call for a very nice compromise in the design of an in-pile pressure vessel.

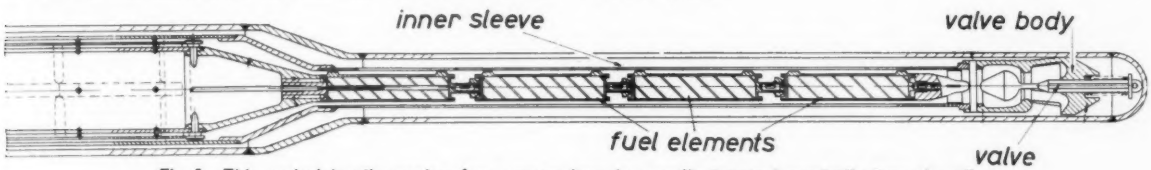


Fig 1 This typical in-pile section for a water loop is actually inserted vertically into the pile, hemispherical end downward. The valve, held open by the bottom of the pressure vessel, closes when the fuel elements are lifted out, trapping water in the inner sleeve. The residual heat of the fuel elements is then dissipated in boiling the water

4. Auxiliary circuits

Attached to the main loop there may be auxiliary circuits performing some function such as gas purification. Thus on water loops there may be an ion exchange circuit, on organic loops a polymer removal system and on gas loops a fission product removal system. Such circuits are frequently developed by the project and incorporate new or little known techniques and are thus particularly prone to sweeping modifications. The design has to ensure that maloperation of such a circuit cannot affect the safety of the loop.

5. Control

The power output from the loop fuel element depends directly on the flux of the reactor which is set by the pile operator. The design has to ensure that the loop automatically functions correctly with variations in the reactor flux. This automatic control is generally based on a limiting parameter in the design and must be designed to fail safe. If the power variation cannot be coped with by the control system, then the reactor must be tripped.

There are two states of tripping on DIDO and PLUTO. Firstly there is 'power reduction' in which the control arms are lowered in at a set rate, reducing reactor and hence loop power. This condition can be reversed if the fault in the loop is put right. The second condition is 'reactor trip' in which the control rods and shut-off rods are dropped into the reactor causing a virtually instantaneous power shut-off. These trips are energized by the connexion of the loop trips onto the reactor guard lines. To avoid spurious trips the loop trips are arranged on a two out of three basis. This means that any particular trip function has three sensing elements, operation of any two of which causes tripping. In the interests of safety all trips fail safe and all trips are operated on their own and not as contacts on an indicator or recorder.

The trip circuits include a 'first up' indicator light showing which particular function has caused the trip. This is convenient as there are usually consequential trips as a result of a shut-down and the operator would be faced with a panel of trip-operated lights and have no means of knowing which was the cause of the trouble. Before the trip levels are reached it is general to incorporate a warning which is both aural and visual. This gives the operating staff the opportunity to remedy a fault before the reactor is tripped. It is permissible to fit warning contacts to indicators or recorders. The reactor control panel has light signals showing which particular loop has a warning or trip on it. It does not indicate which particular function has caused the warning or trip—this is shown on the loop control panel.

6. Servicing

Research reactors run continuously night and day and may have a scheduled shut-down of only 36 hours every three weeks. In this 36 hours any servicing necessary must be carried out. All other loops and experiments in the reactor will also be undergoing maintenance at the same time, and therefore the simpler the servicing can be made the better.

7. Removal of active equipment

Early consideration must always be given to the problem of changing the experimental fuel element, which may carry as much as 10^5 curies of gamma activity. Apart from removing these highly active sources behind shielding, the experimental hole into the reactor has to be shielded against the escape of reactor radiation until it can be plugged or a new fuel element and plug put in. A fuel element change rates as a major operation, but it is desirable to be able to complete the change within the 36 hours shut-down period. It is also desirable that the operation does not require the crane for long periods since this may also be required for changing the reactor fuel elements and for work on other loops.

The problem is aggravated by the residual heating of the fuel element due to the decay of its fission products. In the case of metal canned elements this may well necessitate some sort of cooling being available during handling from the reactor to the storage block and possibly from the storage block to the active handling building where the element is cut up for examination. If any part of the loop, such as a coolant purifier bed, is subject to routine change and is likely to be active, then similar shielding precautions must be taken. The neatest solution, not possible with large loops for space reasons, it to fit the entire loop, circulators

and all, into the experimental hole whence, after breaking power, water and instrument connexions it can be withdrawn into one of the standard handling flasks as a unit.

8. Instrumentation

The measurements required by the project are dealt with first since they provide much of the data to obtain which the loop has been built. Extra instruments are usually required to enable the loop to be properly operated. In addition there are the controls, warnings and trips dealt with under (5). The sensing heads of instruments have frequently to be redesigned or existing production models considerably modified to satisfy the requirements of the loop; a common change is the substitution of stainless steel for mild steel or brass. Another common modification is the strengthening of the case of the sensing head to carry the full loop working pressure. This is done as a precaution against the failure of a diaphragm or bellows inside the unit. Associated with this modification is the making of a leaktight joint between the casing and the body of the instrument and the fitting of a good gland on the electrical leads running from it. If the loop is active a transducer technique must be used for measuring pressures since it is not safe to bring an active fluid to a normal type gauge on the control panel.

9. Disposal

The final removal of the loop from the reactor at the conclusion of its running life must be considered in the initial design stages. Materials with long-lived radioactive isotopes—cobalt for example—are avoided if possible. If parts of the loop are active and will not fit into one of the standard handling flasks a special container must be provided so that they can be unloaded from the reactor and transported without exposing personnel to excessive radiation.

It will be seen that some of these factors are mutually incompatible and different designs can be produced by shifts of emphasis between them. In the event there are usually only two or three practical ways of doing the job at the end of this stage, the others having met some insuperable difficulty or suffered amalgamation with one of the survivors. Other things being equal, the choice falls on the design thought most likely to satisfy the safety committee which examines all proposals for equipment to go in the research reactors.

SOME DETAIL DESIGN SOLUTIONS

After the selection of the most promising design study the detail design is commenced. This is usually bedevilled by lack of data: some of the design information required is frequently that being sought for the project team by the building of the loop. In addition, the physical properties of some of the unconventional materials used in nuclear reactors are as yet incompletely known. *Ad hoc* experiments have frequently to be initiated to get some vital piece of information. Out-of-pile development work has also to be started on various loop components, with the object of easing the task of commissioning and saving time should the components have to be redesigned.

The following are solutions to some problems met in the detail design stage for the various types of loops. The headings used are the same as those in the design study section.

1. Maximum safety

1*a*. *Safety as a pressure vessel*

The in-pile sections of water loops present a difficult problem since the pressures are high and a generous factor of safety cannot be allowed for flux depression reasons. The working stress, the sum of the hoop and thermal stresses, has been arbitrarily taken as half the yield stress. A check on the change of properties of the material under irradiation may be kept by inserting Charpy and tensile test specimens in the pressure vessel some of which are taken out and broken at each fuel element change. This method is adopted to ensure similar temperature and flux conditions in the pressure vessel and test pieces. A typical water loop in-pile pressure vessel is shown in figure 1.

1*b*. *Safety as a source of radiation*

It has become quite general practice to put all the plant of a loop in a shielding room. Particular items of plant have their own local shielding to give a few tolerances of activity inside the room. The shielding room reduces this to an acceptable environmental level in the reactor hall.

1*c*. *Safety as a source of leaks*

All loops may have leakage problems. For example it is often required to run a fuel element with a deliberate leak in its can for leak detection experiments. The shielding rooms mentioned in 1*b* above are kept at a subambient pressure and vented outside the reactor hall. However, in the case of the gas loop mentioned earlier an unacceptable amount of activity might be discharged to the atmosphere. This loop is therefore enclosed in three concentric containments. First the primary which is also the pressure vessel, then the secondary which dilutes and delays fission products escaping from the primary circuit and lastly the tertiary containment which is formed by sealing off the shielding room. In this case the secondary circuit is sufficiently active to require gamma radiation shielding, but the tertiary containment can be vented straight to the atmosphere. The ventilation duct carries shut-off valves operated by an activity monitor so that the containment is automatically sealed in the event of excessive leakage.

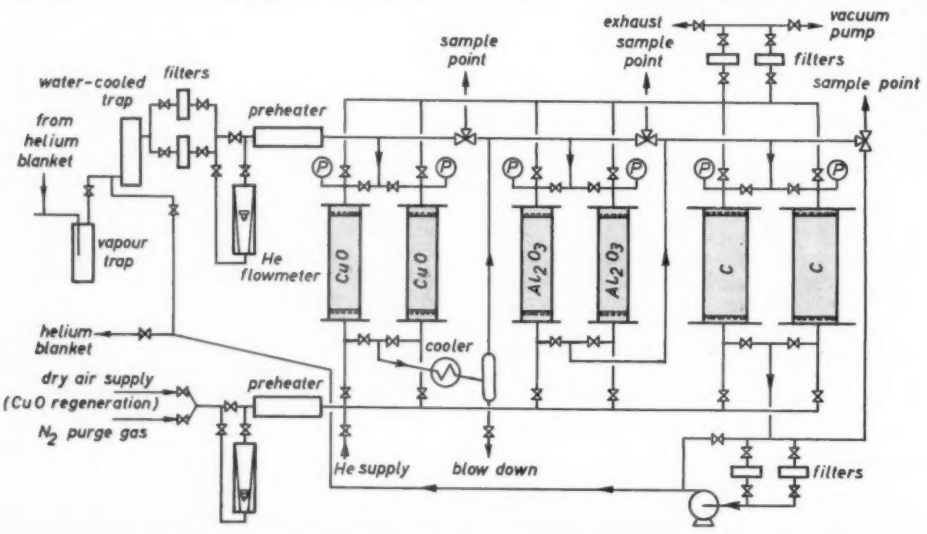


Fig 2 Hydrogen and hydrocarbon are produced in the helium blanket of an organic loop by polymerization, irradiation and heat and are removed by this purification system

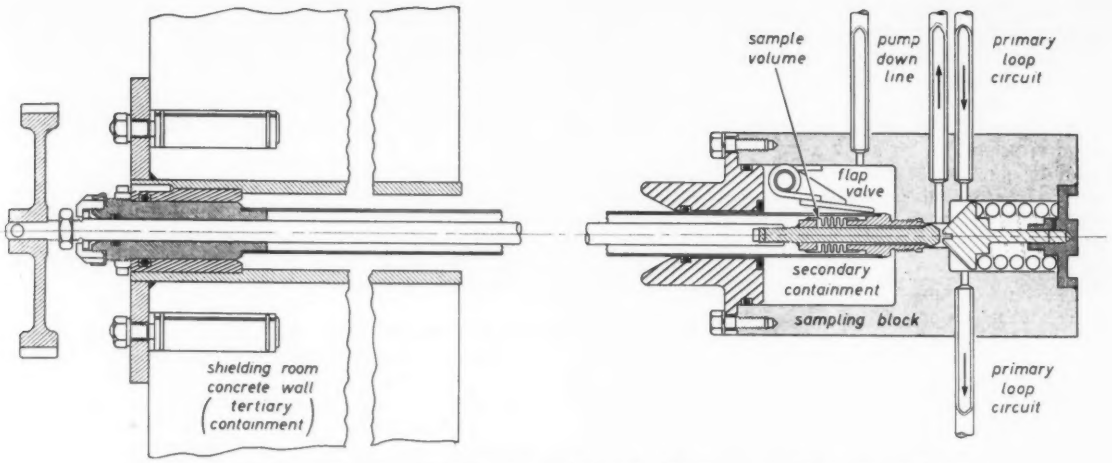


Fig 3 Measurement of some parameters are made under laboratory conditions on specimens taken from the loop. This sampler for a gas loop is designed for use while the loop is in operation

Care must be taken to ensure that there is no by-passing of any of the containments. In the loop in question the primary circuit heat exchanger is supplied with water from the reactor cooling system which circulates through cooling towers. To prevent a leakage from the primary circuit escaping from the cooling towers via the water system, water and gas are piped separately and thermally linked by an aluminium block cast round them.

2. Reliability

Complete reliability can only result from much running experience. This is not yet available. Attention has therefore been given to enabling a fuel element to be easily withdrawn from the high flux zone so that, in the event of a loop failure, the reactor can be restarted quickly and the remaining experimental work proceed. Speed is essential because DIDO and PLUTO poison out in less than an hour due to the build up of xenon poison on shut-down. Once poisoned out the reactor cannot be started until sufficient xenon has decayed, which takes about 36 hours. A speedy removal of a faulty loop can therefore save up to 36 hours reactor running time.

There are two possible ways of lowering the fuel element flux: by screening the fuel element with a black absorber —this is impracticable since such an absorber would cause flux depressions in adjacent experimental holes—or by moving the fuel element, either inside the pressure vessel, which is undesirable on grounds of unreliability of mechanisms inside the loop, or by moving the whole loop in and out of the reactor on a shielded trolley. This method has been adopted for a recent gas loop, the fuel element being taken from a high flux position a distance of six feet so that it rests within the biological shield of the reactor. The residual heat of the element and the fission heat due to streaming of neutrons down the vacant part of the experimental hole into the fuel is carried away by a secondary coolant circuit running outside the pressure vessel. It was hoped that the trolley could be withdrawn automatically and the reactor need not be tripped, but consideration of the change of reactivity produced by movement of the element showed that the reactor would have shut down on a reactivity or period trip and the scheme was abandoned. The loop trips have therefore been arranged to shut down the reactor, the trolley is wound out by hand, and the reactor then restarted. Power, water and instrument lines are connected to the trolley by flexible leads and no connexions have to be made or broken before the trolley is moved.

3. Nuclear effects

The heat output of the fuel element is proportional to the effective cross-section of the fissionable material in it and the thermal neutron flux in which it is situated. The flux in the empty experimental hole is known by direct measurement but the considerably lower value of the flux when the loop and its fissionable material are inserted must be calculated, the most recent method being that due to Hicks described in AERE RR 2418. This method is based on a simplified theoretical treatment with constants derived from experiments in the zero energy reactor DIMPLE. Correlation with the predictions has been sought by measuring the flux in loop in-pile section mock-ups at very low reactor powers on PLUTO, under which conditions no cooling and shielding were required. Neither calculations nor experiments can take account of variations of flux distribution caused by neighbouring experimental hole loadings and control arm positions.

Associated with these calculations is the estimation of the amount of reactivity controlled by the loop, partly to enable the reactor loading schedule to be determined but also for reactor safety reasons. In the case of the loops considered here this amount is usually small since the negative Δk due to the pressure vessel counterbalances the positive Δk due to the fuel element.

The effect on the reactivity of loop emergencies, such as the loss of coolant from the in-pile section, must also be considered. In the case where the coolant is a heavy absorber its sudden loss would have a large effect on the reactor control system.

4. Auxiliary circuits

Figure 2 shows the blanket gas purification system for an organic loop. The system is required to remove from the helium blanket gas the hydrogen and hydrocarbons produced by polymerization of the coolant, by irradiation and heat. The gases flow through a vapour trap and a water-cooled trap which remove coolant vapour, followed by one of a pair of ceramic filters and thence through a preheater to a copper oxide bed operating at 350°C which converts hydrogen into water. The gases are then cooled to room temperature, the cooler removing the heat of reaction of the $CuO\text{-}H_2$ reaction as well as cooling the gases. They then pass through an alumina bed at room temperature which absorbs the moisture, followed by an activated charcoal bed to absorb hydrocarbons. Passing through one of a pair of filters the gases are pumped back to the loop. All beds are duplicated so that regeneration can take

place while the loop is running. The copper oxide bed is regenerated by the passage of dry air at 350°C and the alumina bed is reactivated by the passage of dry nitrogen at 250°C. The activated charcoal is regenerated by evacuating the bed and pumping out for 24 hours at a bed temperature of 150°C. Great care must be taken to ensure that it is impossible to operate the many valves in such a manner as to release the helium blanket pressure. Fission products are likely to be retained in the vapour and water-cooled traps and also in the first filters and the charcoal beds. Arrangements must be made to shield these items and their removal may present an active handling problem.

This circuit is typical of the sort of apparatus which has to be accomodated, shielded, instrumented and have

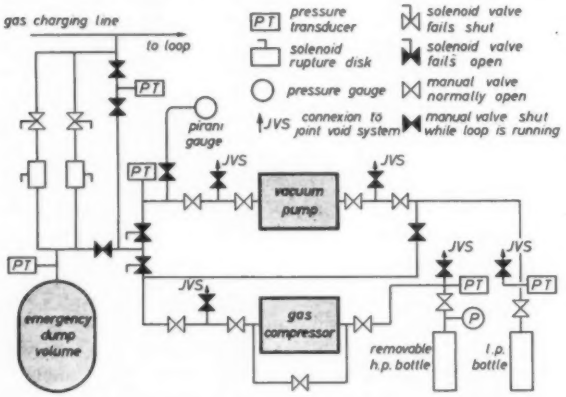


Fig 4 Gas from a gas loop is likely to be contaminated and has to be taken off and stored under pressure. For this a vacuum pump and compressor circuit is used

power and water supplied. There may be two or three such circuits on a major loop.

5. Control

The temperature rise across the experimental fuel element is controlled by the mass flow of coolant past it. This is achieved by varying the delivery of the coolant circulator which is almost universally a totally enclosed centrifugal pump, driven by a squirrel cage motor from a high frequency variable speed generator. This is a better system from the point of view of reliability than operating a by-pass valve.

The datum temperature of the loop, in the case of gas loops, is often controlled by an electric heater following a water cooler. Since most of the thermal resistance of a gas/water heat exchanger is on the gas side, variation of the water flow makes very little difference to the quantity of heat removed from the gas. The cooler is therefore made too large and the overcooled gas passes through a reheater controlled by a thermostat.

6. Servicing

Some of the measurements required from a loop cannot be obtained without the use of instruments not reliable enough for incorporation in the loop. In this case samples are taken from the loop to the necessary apparatus which can then be operated under laboratory conditions. This has the additional advantage of enabling more sensitive activity measurements to be made since there should be a much lower radioactive background in the laboratory than in the reactor shell.

Figure 3 shows a sampler for the gas loop described above. The samples have to be taken with the loop running when it is not permissible to enter the tertiary containment. The sampler is designed so that every joint can be proved sound before any operation by the use of an activity monitor on the gas passing along the pump-down line. The sampling block carries a dummy sampler during normal running. If the sampler is correctly used it is impossible for the loop gas to escape. If the equipment is incorrectly used it is possible to discharge the contents of the loop into the pump-down system and the secondary containment system. Although this would not affect the safety of the system it would be very inconvenient and the sampling device is kept locked so that only trained, responsible staff can handle it.

7. Removal of active equipment

The problem of disposing of fuel element residual heat during handling has already been mentioned. In the case of the water loop a simple answer is illustrated in figure 1. The pressure vessel is vertical in the reactor and the valve shown at the bottom of the stack of fuel elements is held open by the bottom of the pressure vessel. When the elements are lifted out on the inner sleeve the valve closes and traps the water in the inner sleeve. The fuel element temperature is then controlled by allowing the water to boil.

The problems of the gas loop are rather different. The fuel element can lose its residual heat by radiation since the can is capable of running at high temperatures. One difficulty is to accommodate the contaminated gas in the loop, before opening the loop to remove a component. Since it is not intended to re-use the contaminated gas it must be compressed and taken away. To keep the size of gas cylinder and its weight of shielding down to reasonable dimensions a high pressure must be used, while to remove as much gas as possible the loop must be pumped down to the limit of the ability of a mechanical vacuum pump. A vacuum pump does not deliver against a high pressure and so a second compressor must be used. A typical pump-down circuit is illustrated in figure 4. It is connected to the loop by two manual valves but after these have been opened the operation of the system is controlled remotely by solenoid valves. The loop contents can be dumped remotely but this is an emergency measure. Before removing any particular item of this circuit for repair or servicing the manual valves on each side of the item would be proved to be sealed by use of the joint void system, which pumps down and monitors the space between the pairs of valves.

8. Instrumentation

Thermocouples for temperatures of over 1000°C to be sited in a high flux have to receive special consideration since the elements normally alloyed with platinum to make couples for this temperature range have a very large neutron capture cross-section. This results in the composition of the alloy changing with time, hence altering the temperature/emf characteristic of the instrument.

9. Disposal

It is not proposed to discuss instrumentation more fully or disposal since these aspects will more suitably be dealt with in the third and fourth articles of this series.

In conclusion it can be said that the loops under discussion here are in effect little reactors and like reactors they must work safely from the moment they start running active. This is the main reason why many man-months are spent on their design, the cost of which may well be over 30 per cent of the installed cost of the loop.

Acknowledgments

The author's thanks are due to the UKAEA for permission to publish this article, to the De Havilland Engine Co Ltd, for permission to use one of their drawings and Mr G. Lester, UKAEA, for the flow sheet of the organic loop gas purification system.

Heat extraction in power reactors—2

by G. BOXER, Ph.D.
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Continuing a new series begun last month, this article summarizes the salient features of heat extraction from the core

ONE OF THE AIMS in the design of a nuclear power reactor is the extraction of the largest amount of heat from the reactor core. Together with a high overall efficiency this will give the largest electrical output from the turboalternators. Furthermore, the rate of production of plutonium 239 from neutron capture in uranium 238 will increase as the rate of heat production increases.

The problem of heat extraction from the core is influenced by various factors including:

the need for large pressure vessels with their unique fabrication difficulties

the need for expensive heat exchangers

the use of unusual and exotic materials such as zirconium.

The amount of energy available from fission is clearly unlimited, the restriction on heat production being imposed by the heat transfer characteristics of the reactor core.

In the case of a uranium fuel element and its sheath in a concentric coolant channel in the core, the heat transferred to the coolant in unit time over a temperature drop $\triangle T$ from the sheath is given by

$$Q = hA\Delta T$$

or Q is proportional to ΔT and also to h

where h is the local coefficient of heat transfer from the sheath surface to the coolant and, as demonstrated in the first article, is a function of the properties of the fluid used, the rate of pumping of the fluid and the system geometry. The choice of a particular coolant, e.g. air, CO_2, water etc., depends on many considerations including the heat transfer characteristics, nuclear properties and corrosion characteristics. The heat extracted from the core will increase as the rate of pumping is increased, the restriction being imposed in this case by the permissible pumping power.

There is a conflict between the desire to raise the heat production rate as far as possible and the desire to use cheap fuel, i.e. low enrichment. The two considerations are:

Heat transfer requirement—the surface area A of the sheath available for convective heat transfer to the coolant stream should be arranged to give the largest possible value to the ratio A/V, where V is the fuel volume.

Fuel cost requirement—for low enrichment, A/V should be low.

The use of a given lattice design in the past has dictated the value of A/V. However, in future reactors adequate surface area A will be available especially with homogeneous fuels, i.e. liquids in intimate mixture, which have high volumetric heat rates. The Calder Hall design is characterized by the use of extended sheath surfaces in the form of fins. The value of A/V in this case is restricted by the limitation imposed by excess neutron leakage and absorption due to the extra surface area available.

A second conflict occurs in the value of the temperature of the coolant at reactor outlet. In this case we may say:

a. for a high heating power and a reasonable overall plant efficiency this temperature should be as high as possible

b. for good heat transfer characteristics from the sheath surface to the coolant a large value of ΔT is desirable. Since, however, there is an upper limit to the value of T_s, the can surface temperature, determined by the maximum permissible fuel element temperature, the coolant outlet temperature should be comparatively low.

A compromise between these two considerations must be effected.

As pointed out above, the sheath surface temperature T_s is directly related to the fuel element temperature, T_F. The

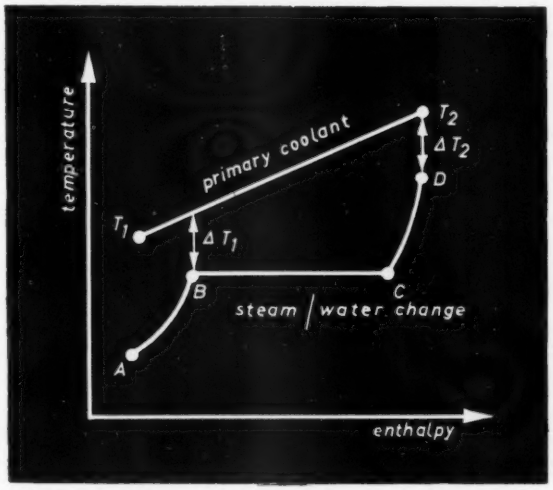

Fig 1 Conditions in the steam/water side of the heat exchanger: A-B feed water heating, B-C evaporation, C-D superheating; $\triangle T_1$ and $\triangle T_2$ are points of minimum temperature difference called temperature approaches

value of the latter is determined at its upper limit by the following considerations:

Alpha-beta stability of uranium—at approximately 650°C the phase change from alpha-uranium to beta-uranium occurs with a 0·4 pc increase in specific volume. This leads to fracture and metallurgical difficulties.

Mechanical strength of other materials. The value of T_s is also determined in part by the sheath strength and deterioration. The sheath material in the Calder Hall design, *Magnox C*, can stand up to 400°C maximum.

Chemical compatibility—the value of T_s will affect the corrosion rate between the sheath and the coolant.

A third complication occurs in the value of the temperature difference between the feed water returning to the heat exchanger and the temperature of the reactor coolant in the

heat exchanger just before entry into the core. Figure 1 illustrates graphically conditions in the heat exchanger and we may say that:

a. for higher temperature steam and thus higher steam side efficiency, ΔT_1 should be low for a given variation in the temperature of the reactor coolant

b. for a small heat exchanger area, ΔT_1 should be large.

A compromise is generally effected in this case on economic grounds. Similar arguments apply to ΔT_2.

Main sources of heat production in the reactor

Heat energy is liberated from three main sources in a nuclear power reactor:

1. approximately 90 pc of the heat is produced by fission in the fuel elements and by slowing down of the fission fragments
2. approximately 5 pc is produced by neutron slowing-down in the moderating system.
3. the remainder is produced in the reflector, shields and pressure vessel.

The following arguments are based on the assumption that only the first two sources are present and the last is neglected. Furthermore, attention is focused on a heterogeneous system of uranium rods and graphite moderator with clearly defined physical boundaries between the reacting elements.

Modes of heat transfer in the core

The two predominant modes of heat transfer in the core are:

thermal conduction through the fuel elements and sheath to the sheath surface

forced convection from the sheath surface to the coolant stream.

Estimation of radial temperature gradients in the fuel elements, sheathing and coolant

1. Neutron flux and heat distribution in the core

Figure 2 shows the distribution of neutron flux both radially and axially in the core.

If ϕ_0 is the neutron flux at the core centre O, the flux at any point in the core can be shown to be:

$$\phi = \phi_0 J_0(ar) \cos bz \qquad (1)$$

where: J_0 is the zero order Bessel function,

$a = \dfrac{2{\cdot}4048}{R_1}$ (the first root of the J_0 function is 2·4048)

R_1 is the extrapolated radius at which the radial flux is just zero

$b = \dfrac{\pi}{L_1}$ where L_1 is the axial extrapolated length.

Furthermore the fission rate at any point in the core is proportional to the flux at that point, and the heat rate at that point is proportional to the fission rate at that point. (1 watt is equivalent to $3{\cdot}1 \times 10^{10}$ fissions/sec)

Thus $H = H_0 J_0(ar) \cos bz$ (2)

where H is the rate of heat production at any point in the core,

and H_0 is the rate of heat production at the core centre O.

2. Simplifying assumptions

With reference to figure 3 the neutron flux distribution is seen to be non-uniform over the fuel element cross-section. The flux is depressed radially over the element due to neutron absorption in the elements themselves. The overall radial flux distribution is thus modified as shown in the figure. The resulting 'fine structure' is a complication which will be neglected in the following analysis, a comparatively small error being introduced. Thus we shall assume that

$H = F(z)$ as against the actual relationship $H = F(r, \theta, z)$.

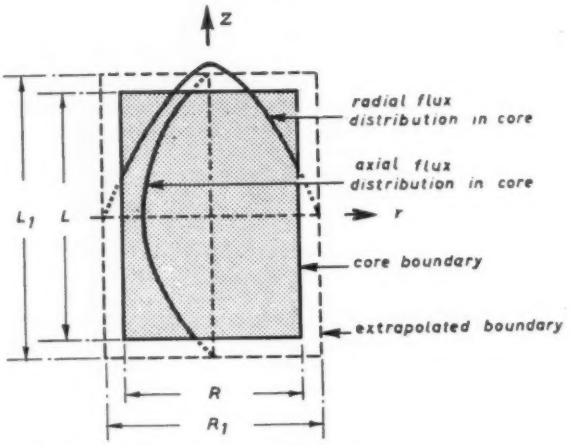

Fig 2 Radial and axial distribution of flux in the core

Axial heat conduction will be ignored for the time being and all the heat generated is considered as being transferred radially outwards to the coolant stream. Axial temperature distributions will be discussed later.

3. Temperature distributions in the fuel elements based on above assumptions

1. *Circular fuel element*

Referring to figure 4a, for steady, radial conduction of heat energy the following simplification of the full Fourier equation for thermal conduction results:

$$\frac{\partial T}{\partial t} = \frac{\partial^2 T}{\partial \theta^2} = \frac{\partial^2 T}{\partial z^2} = 0$$

Thus a simple one-dimensional system evolves:

$$-k_0 \left[\frac{d^2T}{dr^2} + \frac{1}{r}\frac{dT}{dr}\right] = H \qquad (3)$$

$$\text{or } \frac{-k_0}{r}\frac{d}{dr}\left[r\frac{dT}{dr}\right] = H \qquad (4)$$

The solution of this equation is:

$$T = \frac{-Hr^2}{4k_0} + C_1 \ln r + C_2 \qquad (5)$$

Since there must be a finite temperature on the fuel element axis (T_F), C_1 must be zero and for a solid fuel element

$$T = \frac{-Hr^2}{4k_0} + C_2$$

$$\text{or } T_F - T_f = \theta_F = \frac{Ha^2}{4k_0} \qquad (6)$$

$$\text{and in general } \theta = T_F - T = \frac{Hr^2}{4k_0} \qquad (7)$$

where T_f = fuel element surface temperature

a = radius of fuel element

T = temperature at any general point in element, at radius r.

2. *Flat plate fuel element*

Referring to figure 4b, ignoring axial conduction and assuming steady, one-dimensional heat conduction, the Fourier equation now becomes

$$-k_0 \frac{d^2T}{dx^2} = H \quad (8) \qquad \text{since } \frac{\partial T}{\partial t} = \frac{\partial^2 T}{\partial y^2} = \frac{\partial^2 T}{\partial z^2} = 0$$

The solution of this equation can be shown to be

$$T = \frac{-Hx^2}{2k_0} + C_3 x + C_4 \quad (9)$$

Assuming identical heat transfer conditions on either side of the fuel element vertical axis, with no abrupt changes in the value of $\frac{dT}{dx}$,

at $x = 0$, $\frac{dT}{dx} = 0$ and thus in equation (9), $C_3 = 0$

$$\text{Thus } T = \frac{-Hx^2}{2k_0} + C_4$$

$$\text{or } \theta_F = T_F - T_f = \frac{Ha^2}{2k_0} \quad (10)$$

$$\text{and generally } \theta = T_F - T = \frac{Hx^2}{2k_0} \quad (11)$$

3. *Spherical fuel element*

Modifying the original equation for thermal conduction in a sphere to allow for a finite constant value of H

$$\frac{d^2T}{dr^2} + \frac{2}{r}\frac{dT}{dr} = -\frac{H}{k_0} \quad (12)$$

Equation (12) may be solved by substituting the new variable $P = \frac{dT}{dr}$ and the resulting equation is then

$$\frac{dP}{dr} + \frac{2P}{r} = -\frac{H}{k_0} \quad (13)$$

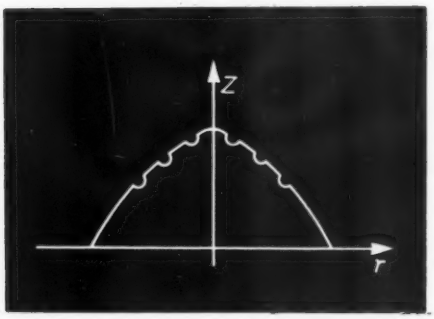

Fig 3 Neutron flux distribution over fuel element cross-section

Equation (13) may be solved with the aid of the integrating factor which in this case is

$$e^{\int \frac{2dr}{r}} = r^2.$$

Thus multiplying throughout equation (13) by r^2,

$$r^2\frac{dP}{dr} + 2Pr = -\frac{Hr^2}{k_0}$$

$$\text{or } \frac{d}{dr}(Pr^2) = -\frac{Hr^2}{k_0} \text{ which on solution gives}$$

$$Pr^2 = r^2\frac{dT}{dr} = -\frac{Hr^3}{3k_0} + C_5$$

$$\text{or } \frac{dT}{dr} = -\frac{Hr}{3k_0} + \frac{C_5}{r^2}$$

$$\text{Thus } T = -\frac{Hr^2}{6k_0} - \frac{C_5}{r} + C_6 \quad (14)$$

and for a finite temperature at the sphere centre, i.e. at $r = 0$, $C_5 = 0$

$$\text{or } T = -\frac{Hr^2}{6k_0} + C_6$$

$$\text{Thus } \theta_F = T_F - T_f = \frac{Ha^2}{6k_0} \quad (15)$$

$$\text{or generally } \theta = T_F - T = \frac{Hr^2}{6k_0} \quad (16)$$

4. Concept of heat rating

This is defined as the heat produced per unit mass of fissionable material per unit time, in watts/gram or in MW/tonne. Thus if H is the volumetric heat rate in watts/cc and ρ is the density of the fissionable material in g/cc

$$H = \rho R \quad (17)$$

where for uranium for which $\rho = 18{\cdot}9$ g/cc, $H = 18{\cdot}9R$

There are two types of rating in use at present:

average rating, R, based on economic grounds

maximum rating, R_0, based on heat transfer considerations and determined by the heat production at the centre of the reactor core.

To give two practical examples for comparison we can consider the temperature differences across the fuel elements of, firstly the Calder Hall reactors, and secondly a high pressure, light water system such as LEO*.

a. CALDER HALL. This design incorporates circular fuel rods for which

$a = 0{\cdot}58$ in., $R_0 = 2{\cdot}6$ MW/T, $k_0 = 0{\cdot}08$ cal/cm/sec °C approximately.

$$\text{Thus } H = 18{\cdot}9 \times 2{\cdot}6 = 49{\cdot}1 \text{ watts/cc}$$

$$\text{and } \theta_F = \frac{Ha^2}{4k_0} = \frac{49{\cdot}1 \times (0{\cdot}58 \times 2{\cdot}54)^2}{4 \times 0{\cdot}08 \times 4{\cdot}186} = 79{\cdot}6°\text{C}$$

b. LEO. In this design there are cylindrical fuel rods for which

$$a = 0{\cdot}5 \text{ ins. and } R_0 = 12 \text{ MW/T.}$$

$$\text{Thus } H = 18{\cdot}9 \times 12 = 226{\cdot}8 \text{ watts/cc}$$

$$\text{and } \theta_F = \frac{226{\cdot}8 \times (0{\cdot}5 \times 2{\cdot}54)^2}{4 \times 0{\cdot}08 \times 4{\cdot}186} = 273°\text{C.}$$

Note.—A useful general rule in the use of rating is to take a 1 inch diameter fuel rod, with $R_0 = 1$ MW/T, for which combination of values, $\theta_F = 22{\cdot}7$°C, remembering that θ_F is proportional to R_0, and also that θ_F is proportional to (diameter)^2.

5. Temperature distribution in sheathing material

Figure 5 shows a diagrammatic arrangement of a circular fuel rod in its concentric sheath. Two main assumptions are imposed on the analysis of temperature distribution across the sheathing material. They are:

no heat is generated in the sheath itself

all the heat developed in the fuel rods is conducted radially outwards from the rod centre to the sheath surface.

Thus modifying equation (5) we may say

$$T_s = C_7 \ln r + C_8 \quad (18)$$

where T_s is the temperature at any point in the sheathing

* LEO—Low Enrichment Ordinary Water—was a design study initiated at Harwell early in 1954. It was fuelled by enriched uranium sheathed in zirconium.—ED.

material at a radius r. Also for the fuel rod itself we may say

$$T_s = -\frac{Hr^2}{4k_0} + C_2$$

We may say also that the heat flux q ($= Q/A$) out of the fuel rod at the fuel rod surface must be equal to the heat flux into the sheath at the same radius, for steady conduction.

Thus from the general Fourier equation for one-dimensional conduction

$$q = \frac{Q}{A} = -k\frac{dT}{dr}$$

or, at radius $r = a$

$$-k_0\left[\frac{dT}{dr}\right]_{r=a} = -k_s\left[\frac{dT_s}{dr}\right]_{r=a} \qquad (19)$$

where k_s = thermal conductivity of the sheathing material.

Differentiating we get

$$-k_0\left[\frac{-2Hr}{4k_0}\right]_{r=a} = -k_s\left[\frac{C_7}{r}\right]_{r=a}$$

or $$\frac{2Hak_0}{4k_0} = -\frac{k_sC_7}{a}$$

or $$C_7 = -\frac{Ha^2}{2k_s}$$

Thus on substituting back

$$T_s = -\frac{Ha^2}{2k_s}\ln r + C_8$$

or at radius $r = a$, $T_{sa} = -\frac{Ha^2}{2k_s}\ln a + C_8$

and at radius $r = b$, $T_{sb} = -\frac{Ha^2}{2k_s}\ln b + C_8$

or $$T_{sb} - T_{sa} = \theta_s = \frac{Ha^2}{2k_s}\ln\frac{b}{a} = 2\theta_F\frac{k_0}{k_s}\ln\frac{b}{a} \qquad (20)$$

e.g. in Calder Hall, where $R_0 = 2{\cdot}6$ MW/T, considering the original aluminium sheaths where $(b - a) = 0{\cdot}06$ ins

$$\theta_s = 2 \times 79{\cdot}6 \times \frac{0{\cdot}08}{0{\cdot}7} \times \ln\frac{0{\cdot}64}{0{\cdot}58} = 2{\cdot}5°C$$

e.g. in LEO, with zirconium sheath for which $(b - a) = 0{\cdot}04$ in.

$$\theta_s = 2 \times 273 \times \frac{0{\cdot}08}{0{\cdot}04} \times \ln\frac{0{\cdot}54}{0{\cdot}50} = 84°C.$$

In both the above design examples, values are given with respect to conditions at the centre of the reactor core.

It is now possible to make an estimate of the outlet water temperature in the core of LEO which will be the highest permissible value with the given conditions. As pointed out in the summary, the limitation imposed in this case is the phase change from alpha- to beta-uranium which occurs at approximately 650°C. If we stipulate that the temperature at the core centre shall not exceed 630°C to allow a small margin of safety, then for an overall temperature change from core centre to sheath surface of 273°C + 84°C = 357°C we see that the sheath surface temperature must not exceed 630°C − 357°C i.e. 273°C. Assuming that the temperature drop into the coolant from the sheath surface is approximately 20°C we find that the maximum coolant temperature in the core is approximately 250°C. (Note that this applies to a system which is pressurized to 1350 psi).

6. Convective heat transfer from sheath surface to coolant

This mode of heat transfer can occur in one of two ways:

by natural or free convection, in which the rate of fluid flow is low enough for the flow to be laminar or viscous. This implies also that the rate of heat flow is low and this mode does not in general pertain in power reactors of the Calder Hall pattern.

by forced convection, in which macroscopic fluid motion is achieved by the use of an agency external to the reactor, such as a blower for CO_2 in the Calder Hall design. The flow is turbulent with Reynolds numbers in excess of 3000.

Heat transfer correlations

In the first article we were able, by means of dimensional analysis, to establish a general relationship connecting the Nusselt number N_u, the Reynolds number R_e and the Prandtl number P_r for the coolant:

$$N_u = \phi\,(R_e, P_r) \qquad (21)$$

This equation can be written in the form

$$N_u = C\,R_e^n\,P_r^m \qquad (22)$$

where the values of C, n and m will depend on the type of reactor under investigation. Copious experimental data compiled by many investigators shows that the following limitations can be placed on the values of C, n and m:

$0{\cdot}0157 \leqslant C \leqslant 0{\cdot}0561$, $0{\cdot}7600 \leqslant n \leqslant 0{\cdot}8300$, $0{\cdot}3300 \leqslant m \leqslant 1{\cdot}0000$.

C and n are determined experimentally from tests carried out with gaseous coolants since the Prandtl number is practically constant for all gases.

The value of m is obtained by cross-plotting using a given Reynolds number. That is, n will be the slope of the line obtained by plotting log N_u/log R_e for a particular value of Prandtl number, and m is the slope of the line obtained by plotting log N_u/log P_r for a particular value of Reynolds number.

For the heating of fluids, which we are concerned with, the most commonly accepted values for C, n and m are:

$C = 0{\cdot}023$, $n = 0{\cdot}800$, $m = 0{\cdot}400$

providing that the Reynolds number is greater than 3000 (i.e. turbulent flow and thus forced convective heat transfer), and that the Prandtl number is greater than 0·500. The latter condition holds good for all gaseous coolants and water but not for liquid metals such as sodium and potassium for which the Prandtl numbers are substantially smaller than 0·500.

Thus for gaseous coolants we may say

$$N_u = 0{\cdot}023\;R_e^{0{\cdot}8}P_r^{0{\cdot}4} \qquad (23)$$

where equation (23) governs the mode of heat transfer by

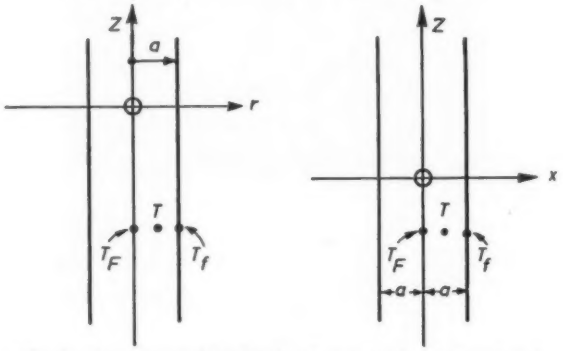

Fig 4 Temperature distribution in **a.** circular fuel rod and **b.** plate type element

forced convection from a hot surface to a colder coolant which is either gaseous or water.

Hydraulic mean characteristic length

The meaning of the dimensionless group called the Reynolds number was explained in the first article in which by definition

$$R_e = \frac{v\rho D}{\mu}$$

where v = bulk mean fluid velocity, ρ = density of fluid, μ = fluid viscosity, D = characteristic length for the flow regime.
D will be equal to the diameter of a circular channel if fluid flows in a duct of this shape.

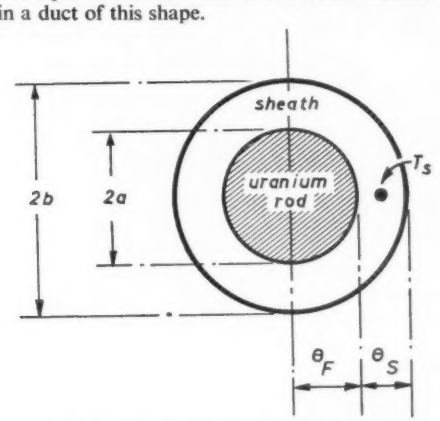

Fig 5 Distribution of temperature in sheath

It is now expedient to introduce a general definition of the characteristic length to cover ducts of all shapes. Thus we define $D_m = 4\frac{A}{P}$ (24) where A = cross-sectional area of flow P = wetted perimeter.
We may now redefine the Reynolds and Nusselt numbers as follows

$$Re = \frac{v\rho D_m}{\mu} \qquad Nu = \frac{hD_m}{k}$$

Thus for a circular channel of diameter D

$$D_m = \frac{4\pi D^2/4}{\pi D} = D \text{ as before}$$

whilst for an annular channel of inside and outside diameters D_1 and D_2 respectively

$$D_m = \frac{4\ \pi\ (D_2^2 - D_1^2)/4}{\pi\ (D_1 + D_2)} = D_2 - D_1 = 2w$$

where w is the annular gap.

Note on the use of D_m

Care must be exercised in the application of equation (24) to channels where the actual flow area is less than the duct area and edge and corner effects such as those illustrated in figure 6 occur.

An approximation to the above simple theory must be made for the case of finned fuel elements. For example in the Calder Hall design in which the fuel elements are encased in sheaths with transverse fins, the value of D_m is taken to be twice the annular gap between the outside of the channel and the tip of the fins.

Equation (23) may be recast in a suitable form for partial solution by graphical means as follows

Let $G = \rho v$ = mass velocity (a constant for a duct of constant cross-sectional area with a constant mass flow).

Then $h = JG^{0.8} D_m^{-0.2}$ (24)

Where (i) $J = \dfrac{0{\cdot}023\ k^{0.6} C_p^{0.4}}{\mu^{0.4}} = F(\text{temperature})$ (25)

(ii) Values of J for different temperatures can be plotted against temperature and the information used graphically for convenience.

Liquid metals

The predominant characteristic of heat transfer to the liquid metals such as sodium, potassium and lead, as distinct from gaseous coolants or water, is the relatively large value of the thermal conductivity involved. This implies a relatively low value of the Prandtl number.

For example for sodium at 400°C, P_r is approximately 0·005, for lead at 400°C, P_r is approximately 0·020.

Heat transfer data for liquid metals

The results of experimental work on the transfer of heat to liquid metals in circular channels may be summarized in the form

$$Nu = 7 + 0{\cdot}025\ (Re\ Pr)^{0.8} \qquad (26)$$

or $Nu = 7 + 0{\cdot}025\ Pe^{0.8}$ (27)

where Pe, the Peclet number is defined as

$$Pe = Re\ Pr = \frac{v\rho D_m}{\mu} \times \frac{C_p\ \mu}{k} = \frac{v\rho D_m\ C_p}{k}$$

or $Pe = \dfrac{G\ D_m\ C_p}{k}$

Equation (26) gives calculated values of the Nusselt number Nu for flow of liquid metals in circular channels at moderately high temperatures which are in good agreement with experimental values. An overestimation in the value of h occurs from the use of this equation when considering the heavier liquid metals such as lead, bismuth and mercury. Common practice in these cases is to assume a value of h equal to 70 pc of that given by the application of equation (26).

The results obtained for flow of liquid metals in annular channels may be summed up as follows

$$Nu = 5{\cdot}3 + 0{\cdot}019\ Pe^{0.8} \left[\frac{r_o}{r_i}\right]^{0.3} \qquad (28)$$

where r_o and r_i are the outer and inner radii of the channel respectively. The limits of accuracy of equation (28) have not yet been established, but its use appears to give satisfactory results for channels in present day reactor design.

To sum up the basic difference between the experimental results for heat transfer to gaseous coolants and water and

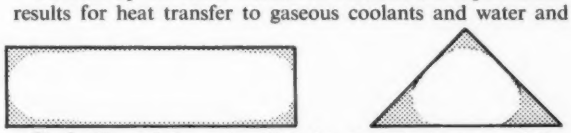

Fig 6 Channel shapes in which the channels do not run full

for heat transfer to the liquid metals, a study of equations (23) and (26) offers the following comparison.

For gaseous coolants in which the Prandtl number is such that $(Pr)^{0.4}$ is approximately unity, for all cases of turbulent flow (i.e. Reynolds numbers in excess of 3000)

$h = Av^{0.8}$ (29) where A is a constant for a given temperature

and for liquid metals we have

$h = B + Cv^{0.8}$ (30) where B is a constant and C is a constant at a given temperature.

It will be seen from equations (29) and (30) that conduction is the predominant mode of heat transfer from the sheath surface to liquid metals giving a comparatively high value of B compared with the term $Cv^{0.8}$

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Fluid density measurement by gamma radiation

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NUCLEONIC DENSITY GAUGES have a number of advantages over conventional measuring systems and as a result they are finding many applications in industry, where they can be used for the location of liquid-liquid and liquid-slurry interfaces, measurement of the specific gravity of liquids, and the density or percent solids of slurries.

The advantage of nucleonic methods lies in the fact that all the measuring components are located external to the pipe or tank containing the material to be measured. Within limits, therefore, temperature, pressure, viscosity, corrosion, abrasion, flow and agglomeration do not interfere with operation. Since the gauges are generally installed on existing pipes and tanks, no extensive modifications to plant or pipework are needed. They can also operate through lagging and in many cases it may be advantageous to do so to maintain the temperature of the measuring head at a reasonably low level.

Development of the nucleonic density gauge has resulted from the widespread industrial use of beta-particle gauges for the measurement of the thickness or substance of a range of materials from tissue paper to cigarettes. The principles and characteristics of such gauges have been widely reported (*1, 2, 3*) but the use of similar methods for density measurement has received less attention.

High counting rate needed

As the measurement is usually required where the fluids are being carried in pipes or tanks of from a few inches to several feet in diameter, it is necessary to use gamma radiation. Caesium 137 is a relatively cheap source of 0·661 MeV gamma rays which are readily absorbed in the depths of fluid normally encountered, and with a half life of 33 years it is particularly suitable for industrial use. Where greater penetration is required cobalt 60 can be used, but its shorter half life of 5·3 years makes it rather less attractive.

As gamma radiation is the result of random disintegration with time, it is subject to statistical variation and therefore the accuracy will depend on the number of quanta detected. To achieve a standard deviation of 0·2 pc, a total of 250,000 quanta must be detected and thus a very high counting rate is needed where a high accuracy is required with short time constants.

Geiger tubes are virtually unusable for this application and whilst scintillation counters are capable of operating at the required speeds, the associated electronic equipment becomes extremely complex. Such counters may be used either with ratemeters or with electrometers, but in both cases it is difficult to obtain the required stability due to changes in gain caused by variations of the h.v. supply to the dynodes. This, coupled with a large (in the present context) and unpredictable temperature coefficient, demands frequent standardization (*4*) and makes the scintillation counter unattractive compared with the ionization chamber in spite of the considerably larger sources required by the latter for the same sensitivity.

Ionization chambers are capable of extreme stability and as they have been extensively used for industrial beta gauging, development of the necessary high stability d.c. amplifiers has reached a high standard and they give an adequate performance. The use of a vibrating reed electrometer, in which the d.c. signal is converted to a.c. by a vibrating capacitor and then amplified in a conventional a.c. amplifier, results in a d.c. amplifier with an insignificant drift, at a cost and with a complexity which compares very favourably with a conventional d.c. amplifier of equivalent performance.

The type of ionization chamber commonly used is the TPA, originally designed for the UKAEA (*5*). This chamber is ruggedly constructed and filled with argon to a pressure of 20 atmospheres, resulting in a current gain of about 30 over an ordinary air filled chamber. To enable small changes in density to be readily detected a null balance, or suppressed zero system, is generally used. In this system the standing current in the chamber is balanced out against a highly stable d.c. supply so that only the changes in chamber current are measured and recorded.

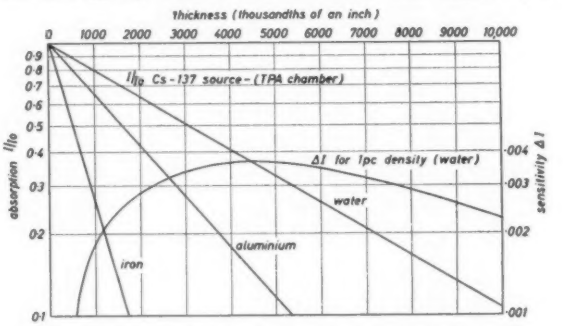

Fig 1 Typical sensitivity curve and associated absorption curve for the system shows that the sensitivity falls away rapidly for small pipe sizes

Gamma radiation is absorbed according to the well-known expression

$$I = I_o \exp(-u_w P_w X - 2 u_p P_p t) \qquad (1)$$

where I_o = original intensity
I = intensity after absorption
$u_w u_p$ = mass absorption coefficients of fluid and pipe respectively
$P_w P_p$ = density of fluid and pipe respectively
X = path length in fluid
t = thickness of pipe wall

The sensitivity of the system is given by differentiating I with respect to P_w which gives

$$\frac{dI}{I} = -u_w X \, dP_w$$

From these expressions it will be seen that the thickness of the container walls does not apparently affect the sensitivity but only the final intensity I. As, however, the current in the ionization chamber is directly proportional to I, it is obviously desirable to maintain I at the highest possible value. This can be achieved by increasing the source strength for the higher wall thicknesses. At first sight it may appear that the sensitivity increases with increasing path length X. This is certainly true when the sensitivity is expressed as a function of I, but it is shown in expression (1) that the intensity is reduced exponentially as the path length increases. When the sensitivity is expressed as a function of I_o, it can be shown that the sensitivity is at a maximum when the path length is such that $I = I_o/e$. A typical sensitivity curve and associated absorption curve is shown in figure 1, from which it will be seen that the sensitivity only changes slowly on either side of optimum, but falls away rapidly for small pipe sizes.

Accuracy determined by noise factor

The random nature of the emission from the source results in a noise component appearing in the current from the ionization chamber and the final reading accuracy will depend on the ratio of this noise component to the current differential resulting from the change in density of the measured fluid. This effect limits the smallest density change which can be detected and is the major determining factor in the overall accuracy of the system. The calculation of this noise signal is lengthy and involves several factors outside the scope of the present paper. The curves of figure 2 show typical values obtained in practice and here again it will be seen that accuracy is lowest for small diameter of pipe.

A typical measuring head is illustrated in figure 3. The source container and ionization chamber are mounted on a transportable cradle which can be adjusted to fit pipes from 4 to 16 inches in diameter and is particularly suitable for use as an interface detector where one equipment may have to serve several pipelines. In other applications the measuring head components can be fitted on permanent pipe clamps or to the sides of a tank. An auxiliary source unit is fitted adjacent to the chamber to enable the equipment to be standardized without emptying the pipe. Both

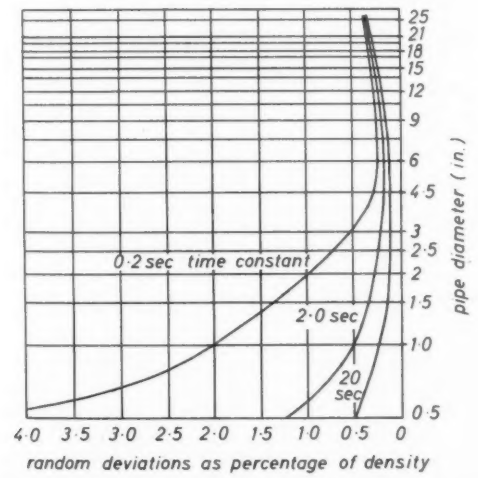

Fig 2 The fact that gamma radiation is a random emission sets the limit on the smallest density change detectable. These typical curves show that the accuracy is lowest for small pipe diameters

sources are contained in lead shields and fitted with safety retraction mechanisms, which are either operated by electromagnets, or a Bowden cable mechanism for cases where the head is used in explosive atmospheres. Since the currents flowing in the chamber circuit are so very minute, the equipment can be readily certified intrinsically safe for use in such atmospheres.

The indicator unit contains all the electronics and associated power supplies and is essentially the same as that used for beta thickness gauges. It incorporates a vibrating

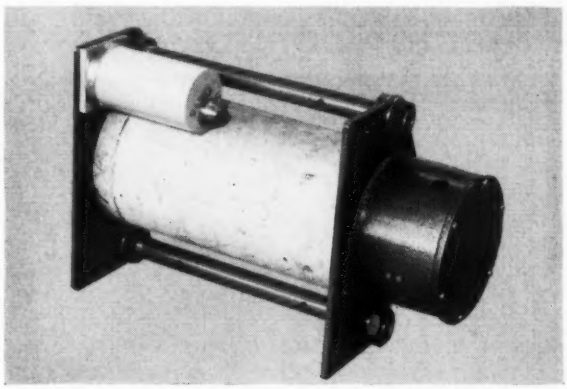

Fig 3 In the measuring head of a typical equipment, the source container and ionization chamber are mounted on a transportable cradle

reed electrometer, deviation meter and precision balancing scale to adjust the equipment to the null balance point for the nominal density of the fluid. A control is provided to adjust the span of the meter to the desired value and a further control is provided to adjust the response time of the gauge to obtain optimum balance between random variations of the meter and process rate of change. The overall sensitivity of the electrometer is adequate to detect changes of ·001 specific gravity under favourable conditions of pipe size.

Instrument has wide applications

Due to the absence of probes or openings in the container, nucleonic gauges enable measurements to be made which were formerly impracticable. New applications are continually being found and the following selection indicates the wide possibilities of the instrument: water content of cement slurries, ash content of washed coal, density of caustic soda outlet from an evaporator, the air content of toothpaste and ice cream, the coal/air ratio in a pulverized coal boiler feed, the density of crushed ore slurries in various mining operations, and measurement of the progressive increase of the density of polymerization products to determine the end point of the reaction.

The equipment is also used in oil refineries to detect the arrival of the interface between successive oil products at the routing valve after being pumped through a common pipe line. In this application the sensitivity is sufficient to detect the interface between aviation, premium, and commercial petrols.

There is no doubt that many new applications will arise as the capabilities of this new instrument are appreciated.

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Boron steel for reactor control rods

manufacture at Hadfields

IT IS NOW WELL KNOWN that the control and shut-off rods at Calder Hall and Chapelcross power stations are of a boron-steel alloy contained in stainless steel sheaths. Boron was chosen in preference to the rare earth and other scarce metals on account of its availability and it was required in the metal form rather than as a compound owing to the disastrous consequences of a leak spreading the material through the reactor. We were recently invited to Hadfields Ltd at Sheffield to see these rods in manufacture for Chapelcross and to see something of the firm's development work.

Hadfields, in common with two other steel makers were invited about ten years ago to undertake the development of high-boron steels but it was soon found that, owing to the extreme brittleness introduced by this alloying element, there was a definite upper limit beyond which the metal cannot be worked. Hadfields soon established that the limit for forging was reached with about 4·75 pc boron, provided some aluminium was added. The alloy steel is now produced for control rods containing 3 pc and 4 pc boron and with this composition it can be cast and machined, or forged, extruded and rolled. With boron up to 2 pc the metal machines like cast iron but with 4 pc carbide-tipped tools and low cutting speeds are necessary. The boron is added to the steel in the form of a ferro-boron alloy containing about 20 pc boron. This is produced by aluminium reduction of boric and iron oxides but trouble was encountered in the early days owing to the presence of trace elements. Manganese in particular was troublesome but this was overcome by selection of suitable hematites. Graphite moulds are used for ingot making and cast tubes are made to a wall thickness of $\frac{1}{4}$ in. using resin-bonded silica sand moulds made in a shell moulding machine.

Tubular inserts

The actual Calder-type rod consists of a $2\frac{1}{8}$ in. o.d., 0·1 in. thick, 18/8 low-cobalt, stainless steel tube about 17 ft long to a straightness standard of 1 in 1500. This contains the boron-steel inserts which are hollow cylinders 12 in. long. The cylindrical form is of course chosen because most of the neutron captures occur near the surface. Containment of the inserts in a stainless steel sheath is necessary because boron steel is very brittle and is also easily corrodible.

At the makers Sheffield works, a boron steel insert for a Chapelcross reactor control rod is finished on a centreless grinder

All inserts are 2·15 in. o.d. but the lowest six contain 4 pc boron and are of $\frac{1}{4}$ in. thickness while the upper 11 are of 3 pc boron steel and are $\frac{3}{8}$ in. thick. The upper end of the rod is formed by a turned stainless steel fitting welded to the tube. This fitting also contains a $1\frac{1}{2}$ in. dia boron insert and is equipped with a fitting for attachment of the cable. The lower end of the rod is fitted with a spring-loaded rod to absorb the impact of a full run-in under scram conditions. To take care of a cable break the shock absorber rod is fitted with a shear pin and broaching device which ensures that no permanent damage is suffered by the reactor or the rod.

Assembling the rods

The boron steel tubes are made by both forging and shell moulding. They are then rough machined dry and then centreless ground to the correct diameter and the ends ground square. Next, they are statically balanced and the heavy sides marked. The inserts are now assembled by threading them on a long rod and arranging the heavy sides so that the complete rod will hang truly vertical. After coating with *Aquadag* the inserts are pushed into the cleaned tubes, and the top and bottom end fittings welded on. The rods are transported in threes in steel tube containers. A complete record is kept of all rods.

In the reactor, neutron bombardment of boron produces alpha particles which become helium but it has been estimated that the useful life of these rods in the Calder-type of reactor is about 20 years.

Hadfields also have under development as neutron shielding, stainless- or mild-steel/boron-steel sandwich plates. These are fabricated by solid-phase welding during rolling, the contact faces having previously been ground flat and the edges welded together before rolling. Boron-steel sandwich plates are being supplied for one of the new nuclear power stations where they will be used as neutron shields inside parts of the pressure vessel which need maintenance and inspection.

An industrial irradiation facility

Metrovick plant available for hire

FOR A NUMBER OF YEARS, Metropolitan-Vickers have been carrying out trial irradiations with a linear accelerator for firms interested in using electron radiation on an industrial scale. On May 29 a new irradiation facility at their Barton works, first described in NUCLEAR POWER in December when it was under construction, was officially opened. Equipped with a standard Metrovick 4 MeV 600 watt machine, it will be available for a hire at an approximate cost of £50 for an eight-hour day. Initial interest is expected to be in such applications as processing of plastics—including polymerization, cross-linking, chain scission and graft polymerization—curing of rubbers, disinfestation of grain, sterilization of pharmaceuticals and dressings, and preservation of food. Metrovick have on show some sausages which were irradiated two years ago and are still in perfect condition. Typical costs per pound of these processes—given in more detail on p 499 of NP December—are: for vulcanization, 1s. 8d. in bulk or 5s. 3d. in mouldings; for treatment of plastics, 8s. or 25s., and for sterilization of drugs, 7½d. in bulk.

Specimens are moved through the electron beam continuously on a conveyor belt comprising vertical *Dexion* strips and there is a specially designed working table with four degrees of freedom for handling articles in small number or with irregular shapes. Both systems are controlled remotely from outside the working area which is enclosed in a thick concrete shield with 4 in. steel facing in some places where scattered radiation was higher than anticipated.

Although operation of linear accelerators involves less safety problems than isotope sources, the facility has certain built-in precautions, such as microswitches on the access doors and at all times it will be operated by skilled staff.

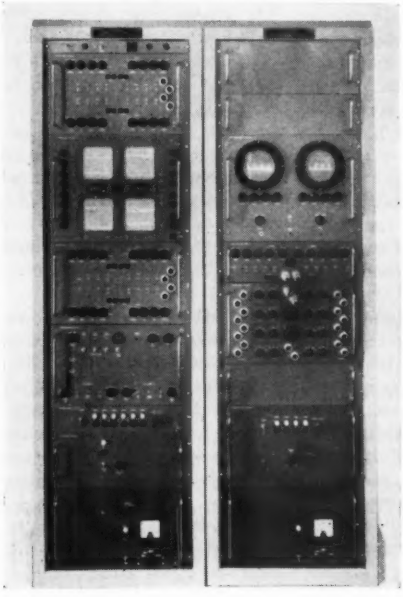
On a speed-controlled turntable a batch of polythene bottles pass the window of the 4 MeV linac. The beam is scanned vertically

Apparatus for further thermonuclear research

improved ZETA oscilloscope shown

AS HAS ALREADY been reported in these pages (*Companies*, March), Cawkell Research and Electronics Ltd (formerly A. E. Cawkell) supplied an 8-channel recording oscilloscope and a 2-channel *Memotron* storage oscilloscope for the ZETA thermonuclear apparatus at Harwell. Recently we had the opportunity of attending a demonstration of a similar but improved equipment which has been developed for further thermonuclear research work at Harwell. The demonstration was held at the works of an associated company, Rotheroe and Mitchell Ltd, at Perivale and it was attended by representatives of the UKAEA, British firms and also workers from research laboratories in the USSR, Poland, France and Czechoslovakia.

The Cawkell Mk2 storage oscilloscope has been specially built for Harwell. There are four channels on two double-gun tubes and the outputs can be switched to the two storage tubes (right)



Like the original apparatus, the new equipment comprises four 20th Century D6B double gun tubes with full facilities for photography, together with two *Memotron* storage tubes (Hughes Aircraft Corporation, USA) onto which can be passed the output from any of the eight channels. These tubes retain until erased any non-recurrent transient phenomenon so that it can be studied in detail. The complete equipment with all its electronics is contained in two 6 ft racks and is claimed to have applications wherever many rapidly changing phenomena require to be accurately measured simultaneously. In ZETA for example the Cawkell apparatus is used for recording and measuring primary current, secondary current, electric field, neutrons, X-rays, spectral lines, total light and the output from Langmuir probes.

Also on view at this demonstration was a new air sampling monitor by Rotheroe & Mitchell Ltd. This is a most interesting instrument and is designed for monitoring alpha radiation from airborne dust. It can detect ten maximum permissible levels of Pu239 in less than one hour. It is hoped to give further details of this instrument in a subsequent number of NUCLEAR POWER.

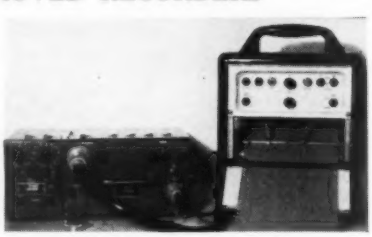
New Product Survey

PLANT · EQUIPMENT · INSTRUMENTS · MATERIALS

EVERSHED INTRODUCE IMPROVED RECORDERS

New quick response recorders with amplifier have recently been introduced by Evershed and Vignoles Ltd. These continuous roll chart instruments incorporate two quick response movements and record electrically on teledeltos paper. The movement zero may be set in any position, and a marker pen is incorporated. Internal illumination is provided.

The CRD 5 has chart speeds of ½, 1, 3 and 6 inches per second, and the CRD 6 speeds of 2, 4, 12 and 24 inches per minute. These speeds are selected by a lever. The front of the recorder hinges open to form a run-out chute for the paper and a writing surface.



Quick response recorder has its own amplifier. Writing surface and run-out chute for the paper is formed by hinged front of the recorder case

The recorder measures approximately 13 by 11 by 6 in. and weighs 35 lb: the separate amplifier unit is 13 by 8 by 6 in. and weighs 26 lb. The latter comprises a power pack and two amplifiers, and an 18-core connector 5 feet long is provided. Power requirements are 115/230 V 50/60 cycles a.c. (140 watt) and 15/20 V d.c. (3 watt) for the marker pen.

Records can be taken up to 25 c.p.s. with an amplitude error not exceeding 10 pc for a peak to peak deflexion of 1½ inches. At smaller amplitudes the frequency response is proportionally higher. Under static conditions the linearity is within ± 3 pct and after warming up the drift is negligible.

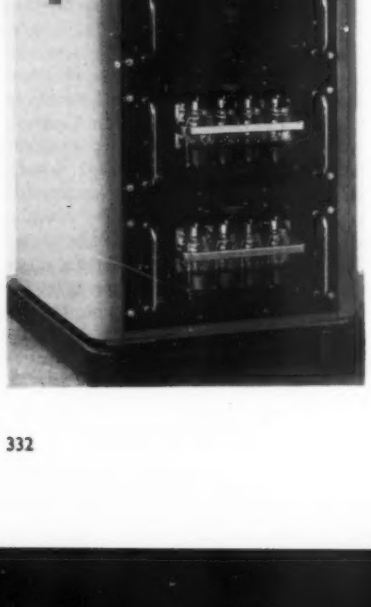
The sensitivity is ± 5 volt for full-scale deflexion of ± 1½ inches, and can be adjusted down to zero by a potentiometer control. With this control in circuit the input impedance is approximately 50,000 ohm, and 2 megohm with the control switched out.

Tick **No 181** on reply card

OSCILLOSCOPE WILL RECORD RANDOM PULSES

The 1239A oscilloscope produced by Redcliffe Industries in collaboration with AERE, Harwell, has been designed to fulfil the need for an oscilloscope that will faithfully record pulses with rise times of the order of 5 millimicroseconds, occurring randomly in time, such as those obtained from a scintillation counter. Such pulses may be viewed direct, or recorded on film together with their time of origin. The oscilloscope may also be used to display recurrent waveforms.

Fully enclosed 4 ft rack houses complete instrument and all units can be withdrawn on racks



A calibrated amplitude discriminator permits display of only those pulses having an amplitude greater than a preset minimum. A paralysis dead time is also introduced to ensure that the oscilloscope cannot re-trigger until it has returned to rest.

A calibrator is incorporated, in the form of a beam switched second trace displaying 10 millimicrosecond marker pips. Displacement of the two traces is effected by means of a voltage calibrated control, which allows measurement of signal amplitude. Four switched ranges of calibration are available, being ·02, ·1, ·2 and 1·0 millimicroseconds.

The time base is generated by a modified bootstrap circuit, and is substantially linear over the 4½ centimetre sweep on all five time base ranges. These switched ranges are 0·1, 0·3, 1·0, 3·0 and 10·0 millimicroseconds.

A recording camera is normally provided as a sub-unit. It can be attached to the front of the oscilloscope by means of the lugs provided. 16 mm. film is used in a daylight loading cassette. A watch together with the necessary illumination is built in to record the time of random pulses, and is simultaneously exposed. A counter records the number of exposures made.

The complete instrument is housed in a 4-ft fully enclosed rack, having a hinged top panel. Considerable emphasis has been placed upon accessibility, all units are withdrawable upon runners, and many units have hinged sub-sections. A very comprehensive range of preset controls and test points facilitates maintenance. The price is £5000 ex works packed ready for shipment.

Tick **No 182** on reply card

COMPARATOR COMBINES HIGH ACCURACY, LOW COST

The *Magna-Gage* electronic comparator by Southern Instruments, Industrial Division, combines the ability to read a total deflexion of ± ·005 in. with an accuracy extending down to ·00001 in. The instrument is small, robust and portable and being insensitive to normal mains and temperature variations can be used with maintained accuracy in any situation. It is simple and easy to use, allowing operation by personnel without special skills and little gauging experience.

Together with its accessories the *Magna-Gage* provides a flexible range of equipment for semi- or fully-automatic indication and control of dimension tolerances. In performance and price the equipment compares very favourably with existing mechanical and pneumatic gauging devices and has the following added advantages. The sealed gauge head can be mounted on a comparator stand or machine in any desired position and the electrical signal wired to the remote indi-

cating unit which can, therefore, be placed in any convenient display position.

A signal light indicator attachment indicates tolerance limits by coloured light signals. This enables sizing or batch sorting of workpieces to be carried out by unskilled operators. Relay outputs are also available from this same unit for automatic sorting or machine control. For example in grinding machine control the first relay contacts can be used to change over to a lower rate of feed when the work is approaching size, and the second to stop the machine after size is reached. A number of other accessories are available for special applications and others are under development which will greatly increase the versatility of the equipment. Reports on the equipment have been obtained from the National Physical Laboratory (England) and the National Standards Laboratory (Australia).

Tick **No 183** on reply card

POWER UNIT FOR B.O.G. ARGON-ARC WELDING

A composite power unit which is designed for use with the argon-arc welding process is now being marketed by British Oxygen Gases Ltd (Industrial Division). Known as the CPU 350, this compact and mobile unit is said to provide maximum productive efficiency when used in connexion with the a.c. welding of aluminium and its alloys up to $\frac{3}{8}$ in. in thickness in a single pass, and the welding of stainless steel up to $\frac{1}{4}$ in. thick.

A remote-control foot switch, coupled with automatic arc starting and control of both argon and water enables welding speed to be increased. After the unit has been switched off, the electrode cools in the protecting argon envelope, the gas continuing to flow automatically for a pre-determined period. This results in economy of gas and ensures that the cleanliness of the electrode is maintained.

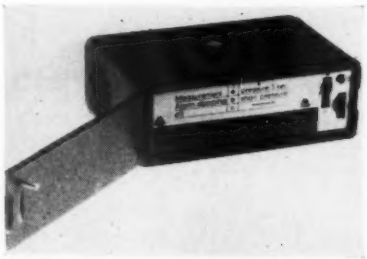
The unit incorporates surge injection, which is the introduction into the arc of a d.c. pulse, timed to coincide with the beginning of the oxide scavenging positive half cycle only. It is of sufficient magnitude to cause the arc to ignite immediately and thus provides a full positive half cycle. Surge injection allows a substantial reduction of open circuit voltage, resulting in a lower transformer rating, together with a reduction in the amount of current taken from the mains.

The composite power unit is suitable for 360/500 volt 50 cycle single phase operation, with a striking voltage of 50 V. Rating is 10·75 kVA continuous or 17·5 kVA at 0·5 duty cycle. Welding current is 25 to 350 amp, and 215 amp continuous.

Tick **No 185** on reply card

GAMMA ALARM GIVES AUDIBLE WARNING AT 30 MR/H

A new pocket ionization chamber alarm unit which gives a loud warning on receiving a gamma dose rate of 30 mr/h is now available from Radiatron. Weighing only $12\frac{1}{2}$ oz, the instrument is transistorized and its batteries provide for



PTW monitor from Radiatron weighs only $12\frac{1}{2}$ oz, gives warning of rise in gamma doserate

2-3 months' operation under normal conditions. They are recharged *in situ* by means of a small mains-operated charger which can be plugged into the instrument.

The monitor has a flat response to radiation energies ranging from under 100 keV to 3 MeV—an important consideration as, in most cases, the radiation is composed of various energies owing to Compton scatter. It is a useful supplement to the pen-type dosemeter which measures cumulative dose, as it gives early warning of a rise in dose rate.

The instrument is fitted with its own calibration source in the form of a small beta source normally housed in a lead-lined container. By placing the source in position on the monitor and using a stop watch and a calibration sheet supplied with each instrument, the operator is enabled to check the instrument.

This new device, which is intended to be a complementary instrument to other types of radiation protection monitors, is particularly valuable when operators are engaged in work in which their hands are not free or where the attention or skill demanded for reading other types of instruments cannot always be depended on.

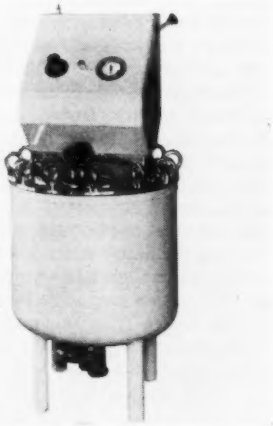
Similar instruments operating on a higher dose than 30 mr can be made for special requirements.

Tick **No 184** on reply card

DIRECT READING OF DISTANCE AND VIBRATION

A new method of measuring distance and vibration has recently been developed by the Wayne Kerr Laboratories. The measurement is made in terms of the capacitance change between a non-contacting probe and the surface under observation, the only requirements being that the surface in question is metallic, or at least metallized, and such that a probe may be offered to it. The probe and test surface must form a parallel plate condenser, though for special applications a shaped probe can be supplied. The advantage of the Wayne Kerr system over a method involving a direct capacitance is that the output is directly proportional to distance so that the reading of vibration is independent of the distance, and the reading of the mean distance is unaffected by the degree of vibration present. The direct readings of mean distance and peak to peak vibration are shown on dials. The vibration is directly related to the modulation of a 50 c.p.s. carrier which may be displayed on an oscilloscope so that the form of the vibration may be examined. For example, if the probe is used to examine a rotating shaft in this manner, the operator can examine eccentricity and play in bearings, as well as the contour of the surface.

Tick **No 186** on reply card



Safety valve, control valve and compound gauge are mounted on the upper panel of the pump

SLURRY PUMP HAS NO MOVING PARTS

Designed for handling dangerous or valuable liquids and slurries where the use of a mechanical pump is ruled out, the Watson-Marlow vessel pump incorporates a vessel adapted for both vacuum and pressure, having as part of its structure a patented control device. This device enables it to use air (or inert gas) pressure to generate internal vacuum as well as pressure. It also arranges that when the vessel is under vacuum it is in connexion only with the source of the material

to be transferred and when under pressure only with its destination. The changeover from one state to the other is effected by moving a single handle a few inches. This operates a simple plug-type switch valve. Apart from this one plug, and then only at the moment of changeover, there are no moving parts whatsoever in contact with the fluid. The suction head is over 19 feet and the vessel can thus be charged across considerable distances or even from the floor below. Operating heads of up to 115 feet (50 psi) are standard and can be higher if specified.

The two standard materials of construction are FMB or equivalent stainless steel and glass. The plug of the switch valve is sleeved with p.t.f.e. for easy operation without lubrication.

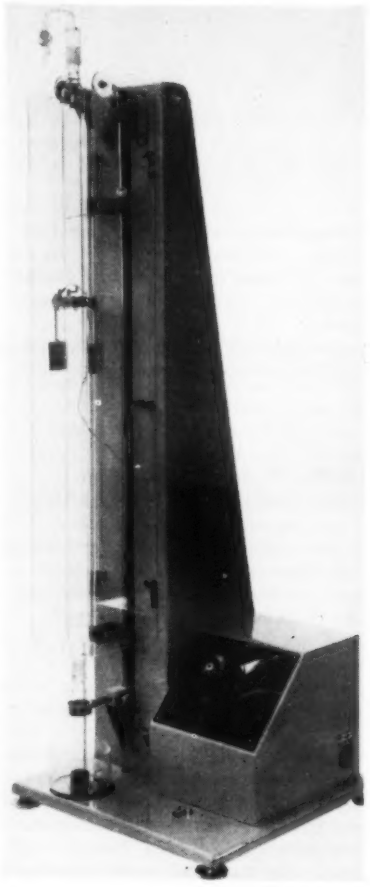
There is no limit to the capacity of the vessel. Standard sizes range from five to five hundred litres. Any size of pump will handle quantities ranging from a few cc's a minute to many gallons per hour with equal facility since only the switch handle needs to be moved to charge or discharge the vessel and the flow-rate in both phases is continuously variable.

Tick **No 187** on reply card

PURITIES OVER 99·9 PERCENT OBTAINABLE WITH B.T.L. ZONE-MELTER

Zone-melting—originally developed for refinement of certain metals, such as germanium—offers a physical method of purification applicable to most solid compounds that are stable at their melting points, and has been used by the DSIR Chemical Research Laboratory for organic compounds. The process is necessarily a slow one, but enables purities exceeding 99·9 pc to be obtained.

The Baird and Tatlock zone-melting apparatus has been developed from the CRL apparatus. The principal feature is a tower with clamp and supports for a vertical melting tube, 3 ft by 1½ in., down which a heater ring travels at approximately 1·3 m/h. This heater is supported by two fine flexible cables passing over four loose pulleys and attached to a horizontal drum which is rotated at a constant speed by a synchronous motor. The tower also carries two adjustable micro-switches, which determine the length of the melting tube traversed by the heater, and a clear Perspex removable cover, which acts as a safety shield for both heater and tube. The motors and gear train for raising and lowering the heater, one fixed and one variable transformer, and a panel carrying the heater control, a pilot light, and mains and heater switches and fuses, are built into a case adjacent to one side of the tower. The other side of the tower carries a bakelite control knob which enables the heater to be wound up and down manually. A glass catch pot is situated under the open end of the melting tube.



The tower supports a 3 ft melting tube down which a heating ring travels at constant speed

Molten material for purification is poured into the tube and allowed to solidify. The heater, which can be adjusted from zero rating to a maximum of approximately 125 watt, is set to give a molten zone with a temperature of 2° to 3°C above the melting point of the substance being purified; this molten zone is 1 in. to 3 in. long, depending on the thermal properties of the substance, and travels down the tube with the heater. When the heater reaches the lower microswitch a solenoid-operated clutch engages the rewind motor, which returns the heater quickly to the upper microswitch, completing one cycle. Any number of cycles may be run automatically, or the heater may be rewound manually as desired. The length of tube traversed by the heater may be varied by altering the positions of the microswitches; the greatest length available gives a cycle of 24 hours.

The impurities are concentrated in the lower portion of the tube and are easily removed by cutting off this part of the tube in the region of the bottom microswitch, or by melting out the lower portion from the microswitch downwards.

Tick **No 188** on reply card

IN BRIEF

Self-adhesive name plates suitable for instrument cases and other applications are now being made by John Gosheron & Co Ltd. They are made in a wide variety of materials and finishes and require merely the pulling off of a backing strip.

Tick **No 189** on reply card

Detel Metal Undercoat (DMU) zinc-rich primer, has been accepted by the Ministry of Supply as a **welding primer.** Destructive tests of spot welded specimens carried out at the British Welding Research Association showed high consistency of results.

Tick **No 190** on reply card

J. P. Hall & Sons announced new range of small high-speed geared **steam turbines** rated from 200 to 1000 h.p. Applications are: fans, pumps, compressors.

Tick **No 191** on reply card

New couplings for high-pressure industrial hoses—the *Twin-Saddle* hose end has been developed by British Ermeto Corporation Ltd. Only standard spanners are needed to make a new connexion and the outer cover is not stripped off.

Tick **No 192** on reply card

New range of **heavy duty cylinders** from 2 to 8 in. dia. are available from Martonair Ltd, Parkshot, Richmond, Surrey. Barrels are seamless steel tubing hard chrome plated: end covers are steel or SG iron. Pressures are: 250 psi for pneumatic, 500 psi for hydraulic operation.

Tick **No 193** on reply card

Special **water still** was recently delivered by Apex Construction Ltd, 15 Soho Sq, London W1 to a university in Ireland. Based on standard model H1OS, it has a condenser in glass for visual observation. From steam at 40 psi, output is 10 gph.

Tick **No 194** on reply card

Book Reviews

Fuel metals

Uranium and Thorium L. Grainger 204 pp. London 1958: Newnes. Price 25s

On the basic nuclear metal—uranium—there is already a great volume of published literature but much of it is not easily accessible and that is often highly specialized and sometimes controversial. It is therefore pleasant to welcome this book by the Chief Metallurgist of the UKAEA Industrial Group, who should of course be in a unique position to write it. Mr Grainger has set out to produce a reasonably comprehensive picture of the technology of these metals from their occurrence and extraction through their uses in the atomic energy industry and in this he has succeeded. This source material is largely 1955 Geneva backed up by later published work so the inquisitive reader will find little absolutely new matter. Nevertheless for those who, while not being metallurgists, have still to deal with these metals, the book manages to pack in pretty well all they need to know.

As is now well known, the phenomenon of uranium swelling is likely soon to be a limiting factor in the British gas-cooled reactor system and Mr Grainger has something to say on this. He suggests that means must be developed so that the uranium can swell without bursting the can and without interfering with the heat transfer process.

The only trouble about the book is that it is likely to have the ground cut from under its feet at the next Geneva Conference. Until then, at least, it is safe. After Geneva, a second edition as soon as possible would be most useful.

Crazy mixed-up scientists

Brighter than a Thousand Suns Robert Jungk. 350 pp. London 1958: Gollancz and Hart-Davis Price 21s

By VE-day in 1945, the Americans had practically completed their first atomic bomb after five years of unprecedented scientific and technological effort, undertaken in the certainty that Hitler was doing much the same. It did not take them long to find out that these fears were quite unjustified and that Germany was not even thinking seriously about bombs. This led to the greatest dilemma of the century—should the whole American bomb effort be kept secret? Should a demonstration bomb be exploded? Should it be used in anger against Japan? For the first time in history the scientist was drawn into international politics in a very direct way and he was faced with a moral problem the like of which most of them were quite unused to dealing with.

In *Brighter than a Thousand Suns*—the title is from a passage in the Bhagavad Gita which is said to have occurred to Oppenheimer as he watched the Alamogordo test—Dr Jungk attempts to analyse the feelings of the atomic scientists during this period and while he arrives at no very definite conclusions he has provided some food for thought.

It is rather remarkable however how the lay critics have seized this book and made it into a best seller practically overnight, because although it is concerned primarily with the men behind the bomb few if any of them emerge as anything more than cardboard figures. Only Oppenheimer and perhaps Teller —seen by Jungk as a sort of Faust/Mephistopheles team— attain anything like personalities, and then only because so much is obtainable on Oppenheimer through his 1954 loyalty hearings. Writing, as he was, only recently, Jungk has had to rely on interviews with the many scientists involved—mostly of European origin, incidentally—and at this range in time they are, in the opinion of this reviewer, subject to considerable hindsight. The trouble is that very few real major participants have yet written their own story although Arthur Compton's *Atomic Quest* was a major contribution. Now that Sir John Cockcroft (spelt incorrectly, as usual, in this book) has retired from Harwell, is it too much to hope that he is at present working on his own memoirs? A record of the British view from a first-hand source is badly needed and in fact is a duty to history.

Dr Jungk's book was written in German and the translation is not all that could be desired. In his efforts to render it into good journalistic English the translator has sometimes gone too far and, as evidenced by some howlers, he evidently is not a scientist. One of the most interesting features of the book incidentally are the footnotes—for example, an extraordinary parallel between the hydrogen bomb and *Moby Dick*.

While it cannot be recommended unreservedly as the last word on the subject, *Brighter than a Thousand Suns* should certainly be read—especially by those still working on nuclear armaments.

Structural metals

Metallurgy of the rarer metals, No 2 Zirconium G. L. Miller, PhD General Editor H. M. Finniston, PhD 2nd edition. 548 pp London 1958: Butterworths Price 70s.

The second edition of Dr Miller's work on the metal he has pioneered in Great Britain has benefited by the release of classified information on every aspect of the subject. It is therefore much more complete and authoritative than the first. On the other hand an excellent American work has become available on the same subject between the publication of Dr Miller's two editions and as a consequence the present volume has to withstand a more searching comparison and criticism than the first, which at the time was unique in its field.

There is in fact a place for both works. The content of the two is very similar but while the American work is a series of original monographs each written by an expert in his own field and directed strongly towards the nuclear aspects of the metal, Dr Miller has produced a coherent textbook well suited to the average reader.

Most of the chapters in this second edition have been expanded which has considerably enhanced the value of the book. Notably there is a new section dealing with crystallographic and atomic structure, the treatment of physical and mechanical properties has been much enlarged and the section on corrosion is more authoritative and definite. An extraordinary feature of a book written by a prominent extraction chemist is the almost complete absence of comparative free energy data. This data was certainly available to Miller and its inclusion would have been of considerable assistance to the reader in considering the different methods of preparation which are otherwise described so thoroughly.

L. M. Wyatt

A Guide to Nuclear Energy R. F. K. Belchem. 77 pp. London 1958: Pitman Price 10s

General Belchem, formerly with TI Nuclear Engineering and now attached to an American nuclear firm, explains the background of nuclear power in terms readily understandable by those without specialist knowledge. A useful introduction to meatier fare.

Cross Section by GRACCHUS

HARWELL had another of their 'confidential' conferences with industry recently on the subject of recent development in reactor technology and, as at the last one, I was struck by the number of people that manage to get into these functions with only pretty remote connexions with the subject. Unfortunately I am not permitted to disclose what took place owing to the nature of the invitation and since the Press was barred I don't suppose much will emerge.

I find it hard to understand why the Authority take up this curious attitude to the Press. Obviously it is not national security and it can hardly be commercial security since all the rival firms are allowed to attend. I have heard it said that the presence of the gentlemen of the Press tends to inhibit free discussion, but after all they are allowed in Parliament, Police Courts and even at the United Nations with no obvious effect on the output of words from these institutions. The Authority is of course very sensitive about the Press, especially the dailies —and I suppose they are afraid that in a free discussion at a fair technical level some correspondents will get the wrong end of the stick (as they certainly do when they get their information through roundabout channels). I understand that recently Schonland summoned a hasty press conference to announce the latest developments with ZETA because it had been learnt that a certain correspondent had got hold of the information anyway and the Authority were terrified to think what he might do with it.

Snooping and speculation on advanced reactors is bound to continue because these really are news and if the Authority is prepared to share their secrets with several hundred representatives of firms it is quite illogical to withhold them from the thousands of others who want to read about them. In any case when national security is not involved I'd have thought that the taxpayer had a right to the information gained at his expense.

WITH NEWS coming in daily about progress at the new nuclear power stations and projects for even more advanced reactors, one is rather apt nowadays to dismiss Calder Hall as old stuff and Chapelcross as just a tiresome sort of carbon copy of its famous forebear. This is absolutely wrong, for Calder Hall remains and will remain a monumental piece of engineering. I have recently been reading the literature of Calder operations and have once again been struck by the brilliance of the work that went into the smallest details. There are in fact three papers: T. N. Marsham (European Atomic Energy Society, Rome, November 1957). H. G. Davey (Institution of Chemical Engineers, January, 1958) and K. L. Stretch (Institution of Electrical Engineers, April 1958). While agreeing amongst themselves on most points, I did however notice one curious discrepancy between two of them. During the initial loading of No 1 reactor Marsham states that no neutron source was used, 'the multiplication of spontaneous fission neutrons being adequate to operate neutron counters installed temporarily in the top graphite reflector.' Davey, on the other hand, says categorically that an antimony-beryllium source was located at the centre of the pile. On this subject, Stretch is silent. It would be interesting to have this small point cleared up.

I also note that both Davey and Marsham and—by implication, though not explicitly—Stretch, are unanimous in blaming most of the small amount of teething trouble encountered on conventional plant items. Apart from the well-known trouble with gas leaks at various points, the only specific item is mentioned by Marsham and he singles out the feed-water regulation as being of great importance. This question of conventional plant reliability was mentioned some time ago in the US by Rickover and there is no doubt that when conventional engineering equipment manufacturers enter this new field they have to wake up their ideas to bring them into line with the high but—and here I quote Stretch — 'far from impossible' standards imposed by nuclear energy. This, incidentally, cannot fail to influence engineering generally in just the same way that the advent of the stressed skin airplane in the thirties brought home to us the virtue of lightness in all types of construction and the necessity of getting down to some realistic stress analysis.

THIS MAGAZINE, as most readers will already know, is shortly to have a stable companion. I was chatting to *CONTROL's* editor Christopher Rivington the other day and he tells me the response from the automatic control and instrument industry has been most gratifying. The first issue, I hear, will contain goodwill messages from that G.O.M. of science Sir Harold Hartley and Minister of Supply Aubrey Jones. Another interesting idea Rivington has had is to invite prominent men in industry to contribute a guest editorial each month. First in an impressive line-up is EMI Electronics' Sir David Mackworth and I'm told he has some pretty provocative things to say.

Control Engineering is of course a fairly new subject and I know there is a widespread desire amongst many engineers to know what it is all about. *CONTROL* is catering for this by starting an educational series by C. M. Burrell and J. K. Lubbock who are lecturing at Cambridge in J. F. Coales' department. Cambridge University have pioneered the academic side of the subject in this country and Coales started a full-time post-graduate course some years ago.

I certainly wish *CONTROL* every success and look forward to seeing the first issue, which is due out on July 10.

LAST MONTH I had occasion to remark on the fact that the City and Guilds of London Institute's Advisory Committee on Technical Authorship did not include the name of any professional journalist. I now find that F. B. Roberts, the editor of an eminent engineering journal, is in fact a member. My mistake arose from the fact that in the official leaflet his initials are given incorrectly. He is also representing the Institution of Mechanical Engineers on the committee and not his magazine. These two facts caused me to fail to recognise his name.

On Record

The Windscale incident made headlines in the daily papers for six weeks. At the same time, there was an outbreak of foot and mouth disease in North Wales which involved the slaughter of some 8,500 *cattle and other animals and held up cattle movement over a large district for a considerable period of time. Yet this incident, so much more serious in its real impact on the public, was given only small and insignificant notices in most of the national papers.* Sir Christopher Hinton.

Just as without any heralding fanfare of trumpets the world suddenly realized that Sputnik was encircling the earth, so we should expect shortly to hear of Russian achievements in the generation of power by nuclear methods. Sir Claude D. Gibb.

INDUSTRIAL NEWSDESK

French welding technique for UK?

The electron beam welding technique pioneered by French workers at Saclay (NUCLEAR POWER, June, p. 272) may be exploited in the Commonwealth by Edwards High Vacuum Ltd. In his statement at the annual general meeting on June 5, the chairman, Lord Wilmot, revealed that the company has been approached by the Commissariat à l'Energie Atomique on this matter. He added that the technique, which 'so interestingly exploits many aspects of vacuum technology,' may well be of far-reaching importance in the production of reliable gas-tight welded materials particularly difficult to fuse because of atmospheric attack. This was immediately of considerable interest in the production of reactor fuel elements.

Irradiation development for sale

BX Plastics Limited is to manufacture and market a full range of irradiated polythene tapes developed by the Tube Investments Research Laboratories at Hinxton Hall, near Cambridge.

Special sizes and thicknesses of tape will be produced, and they will be processed on TI's high energy accelerator where research and development work on the application of the tape will continue.

High energy radiation, states BX Plastics, increases the resistance of polythene to high temperatures and stress cracking. They foresee a wide range of uses for the irradiated tape, particularly in the electrical and packaging industries.

Metrovick get Hunterston order

The 132kV air-blast switchgear to control the output from the Hunsterston nuclear power station will be provided by Metropolitan-Vickers. Announcing its £400,000 order from the South of Scotland Electricity Board the company says that the switching station will be unusual in that practically the whole of the 132 kV equipment will be mounted indoors; the site is on the sea coast in an area particularly prone to atmospheric salt deposit.

The Hunterston station is being constructed by the General Electric/Simon-Carves group but their contract stops short of the switching station. Metropolitan-Vickers is a member of the AEI-John Thompson Nuclear Energy Co which is building the Berkeley nuclear power station. The switchgear for this has not yet been ordered.

The Metrovick order covers the initial requirements of fifteen circuits. Standard outdoor components will be used but by special attention to the busbar and isolator layout the company intends that the station will occupy a rather smaller area than with the corresponding conventional layout. The circuit breakers will be operated by compressed air and the isolators will be hand-operated. This, together with the introduction of ring-type current-transformers mounted in wall or isolator bushings, will eliminate the use of any oil in the main building.

DIDO-type fuel plugs total 700

Delivery of 130 fuel-element shield plugs to Denmark will be started in July by Savage and Parsons Ltd. Similar in design to those produced for the DIDO and

These fuel element shield plugs house 3 'purge' tubes, and a centre plug for removing chemicals from the reactor core

PLUTO reactors at Harwell, each fuel element plug is 4¼ft long and 4¾in. dia. The body is a titanium-stabilized stainless steel tube filled with concrete and iron shot to a density of 350 lb per cu ft, and a 4 in. layer of lead. Also housed in the main tube are three stainless steel 'purge' tubes, through which air or gases can be cleared from around the fuel element, and a centre plug which can be withdrawn to facilitate the removal of water and chemicals from the core of the reactor. The fuel element and cooling sheath is attached to the bottom of the plug by a clamping ring.

The company recently delivered 160 plugs for use in the experimental reactor at Lucas Heights in Australia. When the Denmark order is completed nearly 700 plugs worth about £85,000, will have been produced.

Nuclear insurance for Canada

James Matson, manager for Canada of the UK Royal Insurance Co Ltd, will be chairman of an association including nearly all the fire and casualty insurance companies which has been set up in Canada for insuring owners of nuclear reactors. It is called the Nuclear Insurance Association of Canada and Mr. Matson has formed a headquarters to direct policy at Royal's Montreal office. A fund is to be established to provide cover for damage to reactors and third-party claims resulting from any accidents.

Similar pools are in existence in the US; in Britain the Royal is a member of the British Insurers (Atomic Energy) committee which was formed in August 1956.

British bid for Portuguese trade

A big effort to recapture Britain's lost position as principal supplier to Portugal is to be made by the Federation of British Industries in the Lisbon Trade Fair next summer. Organizers are British Overseas Fairs Ltd and 10,000 copies of a brochure describing the arrangements have already been sent out to British manufacturers and to agents in Lisbon. Timed to coincide with the beginning of the second six-year Portuguese development plan, the Fair is hoped to produce a swing of trade to the UK of £M5-£M6 yearly, which would displace West Germany from the lead which she has held since 1955. About £M375 is to be spent by the Portuguese Government over the six years and the FBI wants to see that British industry gets its share of any contracts which are going. The plan includes an expansion of electricity production by thermal and hydroelectric stations (the existing nuclear energy plan is unaffected), a complete survey of mineral resources and a £M5 technical college on nuclear science. The Fair will have a section on nuclear power which will be supported by a big feature showing the UK lead.

More work on beryllium urged

A call to the Government for a more urgent approach to research is made by the Board of the mechanical engineering research laboratory of the DSIR in its annual report for 1957, published by HM Stationery Office on May 30. 'Spectacular industrial developments,' say the Board,' 'have underlined the need for intensive research on a much larger scale.' It proposes that the laboratory be rapidly expanded in the five years beginning in 1959 and that money spent on it should rise to £M1½ a year by the end of the period.

Examples given of the kind of research badly needed to support industry include work on high pressure techniques to produce entirely new metals by changing crystal structures. Already a nitride of boron harder than diamond has been

discovered in America. Another use of very high pressure is in forming certain brittle materials which cannot be formed at atmospheric pressure. The manufacture of beryllium sheaths for fuel elements is an outstanding example of this. More work on niobium, tantalum and zirconium is needed, stresses the Board, and developments taking place on heat exchangers should be supported by the laboratory.

Quasi-Arc improve electrodes

Modifications to improve the performance of the low-hydrogen type of electrode are announced by Quasi-Arc Ltd. The high weld-metal quality given by these electrodes is dependent to a large extent on the formation of a gas shield round the arc. In the short period of time which elapses after striking the arc and before the gas shield has formed, porosity may occur. To deal with this problem, a paste of special composition has been developed which can be applied to the tip of the electrodes after the normal coating has been extruded on the core wire. The tip is designed to generate shielding gases as soon as possible after the arc is struck. The welder can now deposit a bead without the necessity of 'running back' over the start of the weld to eliminate porosity. Arc striking is easier since repeated tapping or scratching is no longer necessary and the arc strikes as soon as the electrode is applied to the workpiece.

Head named for Dounreay college

The first principal for the new £33,000 technical college at Thurso in Caithness will be Dr W. W. Easton, who is at present lecturing at the Bristol Institute at Edinburgh in chemistry, electricity and mathematics. He is a graduate of Edinburgh University and has worked for ICI, the Glaxo Laboratories and T. & H. Smith, manufacturing chemists. The main task of the college will be supplying juniors for the Dounreay establishment but facilities for more advanced training will also be provided. Building will soon be finished and it is hoped that courses may be started in September. The Atomic Energy Authority is to co-operate by arranging for staff at Dounreay to give lectures to supplement the work of the full-time instructors.

The advent of Dounreay has made a radical change in the attitude to technical education in Caithness. In the past education meant agricultural college work or fishery industry training. That has been altered by the fact that at Dounreay there are opportunities for scientific work which would otherwise have been outside the scope of boys in the area.

The core of the US solid homogeneous reactor TRIGA is at the bottom of a 20 ft well below 16 ft of water. Down the centre runs a pneumatic tube for extraction of short-lived isotopes

'Foolproof' reactor tested in US

Initial tests on US General Atomics' solid homogeneous reactor TRIGA (*Worldview*, Nov 1957) which has been operated at ten times its designed continuous power rating of 10kW, conclusively verify its inherent safety, announces the company. Experiments since it went critical on May 3 have shown that when excess reactivity is inserted the power rise is limited to a safe level by the 'prompt negative temperature coefficient of the fuel elements.'

Using a solid fuel-moderator alloy of 20 pc enriched uranium-zirconium hydride, TRIGA was designed specifically for academic institutions and research laboratories, and the company claims that it is accident-proof. First institution to use it will be the University of Arizona.

The core is at the bottom of a 20ft well below 16ft of water which acts as a shield and allows visual observation. Facilities include a rotary specimen rack which can be turned by a surface crank to permit loading and unloading of containers, and a pneumatic tube for extraction of short-life isotopes which consists of two concentric tubes leading down through the water and to the edge of the reactor core. The specimen is fed in by gravity through the inner tube and is ejected by filling the outer tube with pressurized carbon dioxide.

ACHEMA raises hopes

British firms, and especially members of the Scientific Instrument Manufacturers' Association, were very pleased with the business and enquiries received at ACHEMA—the European Exhibition and Congress of Chemical Engineering held at Frankfurt from May 31—June 8, said president-elect of SIMA, Barrington-Brock, on his return from the exhibition. He added that he was 'most heartened' to see how well UK products compared with those offered by German and other competitors in the chemical engineering and instrumentation field. 'A striking example,' he continued, 'was the very active attention stimulated by the interference microscope by Baker of Holborn—especially since Germany has been regarded as the optical stronghold of Europe.'

Exports of scientific and measuring instruments now account for more than a quarter of the total annual turnover of £M68, according to figures recently made available.

BNF study thorium

A study of the properties of certain thorium alloys is being made by the British Non-Ferrous Metals Research Association. The Council's report for 1957 discloses that particular attention is being paid to mechanical properties at elevated temperatures in relation to the possible use of thorium-base fuel in reactors. Special techniques have been developed to avoid contamination by the metal, which is highly reactive chemically.

The Association's income from member firms and its total revenue have each increased by 25 pc over the last two years; this has enabled new lines of re-research such as in the field of nuclear energy instrumentation and fatigue of structures to be undertaken, but the report adds that most of the extra money is being spent on providing urgently needed elbow room for existing work.

In brief

Poznan Kelvin Hughes fitted up a 9½-ton articulated vehicle and a caravan to show its products at the Trade Fair which opened on June 2. The larger vehicle is now making a four-month tour of Eastern Europe to push sales to the Soviet bloc. Also on view at Poznan were new level controllers by Fielden Electronics Ltd. who showed these overseas for the first time.

25th anniversary Welding Supplies Ltd, who introduced OK *Unitrode*, the basic coated electrode used for welding heat exchangers for Calder Hall, Berkeley and Bradwell, is now 25 years old.

Computer for Germany The University of Stuttgart's new computing centre will have a £50,000 Ferranti *Pegasus* for research on nuclear physics, aerodynamics and the design of precision instruments.

Silicon semiconductors cheaper Texas Instruments have again cut prices; with effect from June 1 reductions range from 20-30 pc for small signal types to 5-15 pc for medium and higher power units. An extension to the factory in Bedford is due for completion in August.

Monitor shown at Ministry At the Ministry of Agriculture, Fisheries and Food recently, a team of engineers led by Dr Denis Taylor, NUCLEAR POWER's consultant instrumentation editor, and technical director of Plessey Nucleonics Ltd, demonstrated to senior technical officers the new Plessey portable transistorized contamination monitor.

Outlook for beryllium The Consolidated Zinc Corporation Ltd have completed an AEA order for production of high-grade beryllium metal in the pilot plant at Avonmouth but say that 'the opportunity for further development by us in this field is at present uncertain.'

Nuclear power for heating The US Lockheed Aircraft Corporation has formed a branch for designing and manufacturing reactors for heat generation; preliminary studies show that they will be competitive with appliances using fossil-based fuels, states the corporation.

Ferranti team with Packard The operations of Ferranti Electric Ltd, Toronto, and Packard Electric Co Ltd, St Catharines, are to be consolidated within the next few months under the name of Ferranti-Packard Electric Ltd. Headquarters will be in Toronto and president and chief executive officer will be Thomas Edmondson, president and general manager of Packard Electric.

Physical Society New president from May 30 is J. A. Ratcliffe, Reader in physics at Cambridge University; he takes over from Dr N. F. Mott who becomes a vice-president. Other appointments are Dr R. W. Ditchburn and A. J. Philpot (vice-presidents), A. G. Peacock (hon secretary), Dr D. A. Wright (hon treasurer), and Dr N. Kemmer, G. B. B. M. Sutherland, W. H. George (ordinary members of council).

STC sell silicon knowhow Standard Telephones and Cables' technique for production of pure silicon for rectifiers and transistors will be used by the American DuPont company under a licence agreement signed by the International Telephone and Telegraph corporation, with which STC is associated. The process, which involves the thermal conversion of silane gas into silicon, was originally developed by Standard Telecommunication Laboratories.

Italian chemical congress Over 100 British scientists were among the 900 who attended the first congress held jointly by the Society of Chemical Industry and the Società Chimica Italiana at Turin from May 27 to June 2. Lectures included one on 'Nuclear Energy' by Sir John Cockcroft; other Nobel prize-winners present were Sir Robert Robinson, Sir Alexander Todd and Professor Chain.

Under one roof A new and streamlined factory has been opened at Redhill by Foxboro-Yoxall Ltd to house all manufacturing facilities previously scattered at Merton, Kidbrooke and Wandsworth.

Bimcam The British Industrial Measuring and Control Apparatus Manufacturers' Association has moved to 9 Argyll St, London, W1. Tel: REGent 0568.

Protective clothing J. E. Lesser & Sons Ltd have formed a new company, Jeltek Ltd to take over manufacture of *Jeltek* protective clothing.

New fuel flow test house Opened on June 6, Firth Cleveland Instruments' test house at the Treforest Trading Estate provides facilities for calibrating and production testing flowmeters, water separators, valves and other fluid handling equipment. It is claimed to be the most extensive and modern of its kind in Europe. A new factory is to be built alongside the present factory and will employ more than 350.

Vacu-Blast Ltd The company, manufacturers of the closed circuit system of shot blasting, have moved into larger premises combining office and works at Bath Road, Slough.

Gem Brushes The company Gem Brushes (Luson) Ltd has changed its name to Gem Power Brushes Ltd.

Dynatron Radio Ltd New factory and offices have been opened at St Peter's Rd, Furze Platt, Maidenhead.

Mullard Ltd To embrace the former communications and industrial valve dept and the government radio valve dept, the Government and Industrial Valve Division has been formed.

Serck Ltd Offices at 60 Trafalgar Sq, London, will now accommodate the London technical staff of Serck Radiators, Serck Tubes and Audley Engineering Co.

Non-destructive testing A summer school on principles and practice is to be held in Manchester from Sept 8-12; it is being sponsored by the British National Committee. Enquiries to the Registrar, Manchester College of Science and Technology.

Boral manufacture in the US This typical 3 in. slab of Boral has been made in the US Brooks and Perkins works by enclosing in aluminium a 1 in. plate cast from a mixture of molten aluminium and powdered boron carbide. It can then be rolled down to produce such items as the ¼ in. thick cylinder shown. The method used in the UK by High Duty Alloys, who produce it for the thermal shield in DIDO-type reactors, differs in that the sandwich 'filler' is made by squeezing the powders

They said...

points from papers, speeches, conferences

Automatic control now?

From a purely technical point of view there is no reason why complex chemical plants should not now be operated under complete automatic control or even why all the power stations in the country could not be run from a central control point. This was said by Sir Christopher Hinton, chairman of the CEGB opening a new head office block at Evershed and Vignoles' Acton factory on June 11. But Sir Christopher went on to say that this was not the whole story and that economic and human factors were involved. Automatic control, he said, was all right as long as the plant was running within its design points: when something abnormal happened it still needed a human being to put it right. There was also the problem of ensuring that the system did not lead to boredom on the part of operators and kept them alert and interested in their job. Congratulating Evershed chairman Mr. J. C. Needham on his splendid new building Sir Christopher said firms were obviously well aware of the pyschological and human problems in industry. He said it was gratifying to find that instruments were made in Britain that previously could only be obtained in the United States.

Closing the ranks

The British instrument industry could treble exports to the Soviet bloc if the present embargoes on trade were relaxed. This is the opinion expressed by Paul Goudime, president of the Scientific Instrument Manufacturers' Association, in a speech at the organization's annual lunch recently. 'Although there may once have been sound strategic reasons for the embargo,' he went on 'recent events have made it all too clear that Soviet scientists are perfectly capable of copying the wide range of instruments which we are not allowed to export. They have ample opportunity to see and discuss them at international exhibitions.'

Commenting on the sometimes 'tragic' duplication in new instrument developments in Western Europe, Mr. Goudime made a vigorous call for more streamlining to produce a combined scientific effort which would not only equal but surpass that which 'looms from the direction of Soviet Russia.' One of the problems posed by a European Free Trade area was that the instrument industries of some of the Common Market countries were highly developed and had become very competitive. At the same time it was difficult to see how one could enter into what was virtually a partnership, if the industries of each country were going to do their best to 'eliminate' those of the others. In this country, at any rate, there was now an

GOUDIME
Effort must be streamlined

interchange of technical information among members of SIMA which 'would not have seemed possible a decade ago.' To avoid duplication a consultancy service has now been set up for member firms to discuss in confidence any proposed developments.

Oak Ridge approach to fusion

An important advantage of the US Oak Ridge National Laboratory's scheme for producing fusion (*Worldview*, June) is that there should be no ambiguity about arrival at a thermonuclear state, as the increase in neutron yield would be so large it could not be accounted for in any other way. This was stated recently at the American Physical Society by the Laboratory's Dr Albert Simon, when giving an account of the concepts involved in the method. Hot deuterium molecular ions are injected into a d.c. magnetic field, which traps them after they have been partially dissociated.

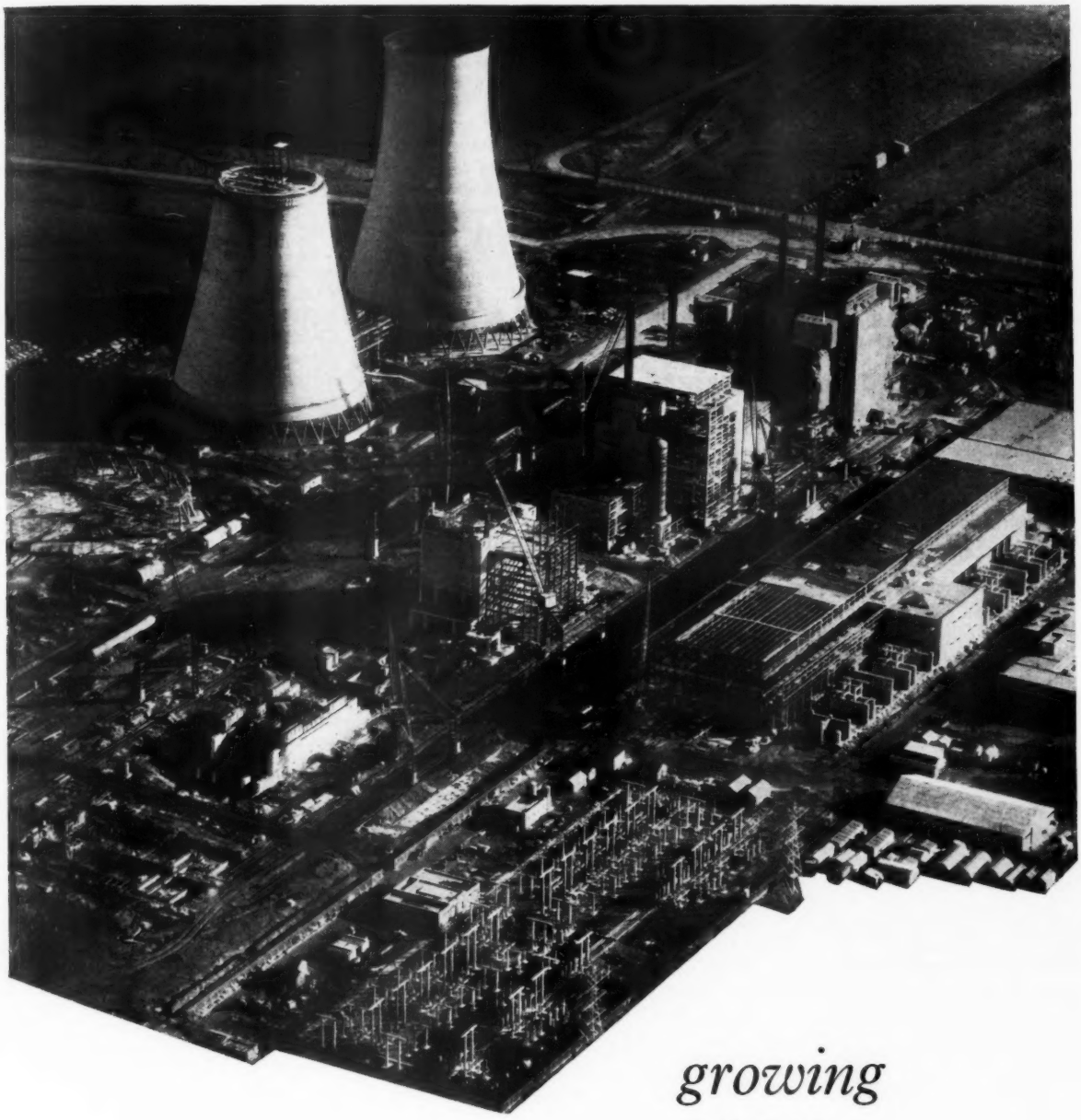
On the arc discharge discovered by John Luce, which has made the system possible by efficiently dissociating the injected ions, he commented that its operation was as yet imperfectly understood. But one possible serious defect is known to be absent; it has been established that less than one in 10^5 fast protons (300keV) suffer a charge exchange in passing through it. Since the presence of the arc may contribute impurities as well as moderately cold electrons which tend to hold down the energy of the plasma, it should be thought of as a plasma 'igniter' rather than as a permanent feature of a thermonuclear device. 'Once a partial plasma has formed,' Dr Simon continued, 'one would hope to shut off the arc and continue feeding the gas by using the molecular breakup occurring in the residual plasma, which if well above the ignition point the high injection could be shut off entirely and cold feed used to sustain and even increase the plasma."

Reactors and politics

What action should a country take if the agreement for the supply of fuel should break down after it has bought a reactor? Paul H. W. Wolff, chief reactor engineer of the English Electric Co's Atomic Power Department, mentioned the problem in a speech on gas cooled reactor economics recently. He pointed out that though every country would like to make a choice of nuclear power plant, in a competitive world market it has to consider the political implications of keeping a reactor running once it is built; the design and composition of fuel is intimately bound up with the reactor for which it is intended and the supply is the monopoly, for their particular style of reactors, of those few countries able to offer them for sale. If the necessary long term fuel agreement should lapse for any reason the position would be complicated by the lack of accurate knowledge of the cost of large plants for manufacturing such materials as uranium, beryllium and graphite. Little is published about these plants either on design or costs because many of them have been erected to fill military needs.

In his lecture Mr. Wolff gave further details of the cost of Hinkley Point nuclear power station. This would be about £120 per kW of which about £55 would be in the reactor, he estimated. This compared with roughly £150 for the first stations to be built for the CEGB, with £80 for the reactor and its associated plant. This reflects the advance in design techniques in the interval, of which the most significant is the increase in the amount of graphite from 30 to 40 pc of the pressure vessel volume. A considerable part of this gain has resulted from the use of an openwork structure of crossed Warren girders for supporting the core instead of the solid plate or box structures previously employed.

Tick **No 94** on reply card for further details



growing apace

Construction of the four Reactor Buildings and Cooling Towers at the U.K.A.E.A. Nuclear Power Station at Chapel Cross is now well under way. The Mitchell Construction Company, as the Main Building & Civil Engineering Contractor for the project, is also responsible for the construction of the Turbine Hall, Sub-Station and other associated works.

CONSULTING ENGINEERS:
Messrs: Merz & McLellan

THE MITCHELL CONSTRUCTION COMPANY LTD

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MITCHELL

P.1721

NAMES IN THE NEWS

The English Electric Co Ltd have elected **Sir Archibald Finlayson Forbes,** GBE, to their board of directors.

Mr Sebastian Z. de Ferranti has been appointed managing director of Ferranti Ltd. Sir Vincent de Ferranti remains chairman of the company.

New chief purchasing officer of Marconi's Wireless Telegraph Co Ltd is **Mr M. W. Munro,** who has been with Marconi's since 1939. The post of chief purchasing officer will supersede that of supplies manager.

Mr S. R. B. Brewer has been appointed a director of Bryce Electric Construction Co Ltd.

Evershed & Vignoles Ltd announce the appointment of **Mr R. M. Wardrop** to be manager of their new Scottish area office in Edinburgh.

Two British businessmen **Mr Robert Asquith** and **Mr Francis Fielding** executives of William Asquith Ltd and Fielding and Platt Ltd have recently paid a short visit to Russia where they inspected machine-tool works and scientific research institutes. They went at the invitation of the State Scientific and Technical Committee.

Mr J. Bell has been appointed manager of the GEC research laboratories at Wembley. He will be responsible for the administration of the three divisions, Physics and Applied Physics, Chemistry and Engineering and Telecommunications.

Mr J. R. Moore has been appointed a director of Fisher Governor Co Ltd, a member of the Elliott-Automation Group.

Chamberlain and Hookham Ltd have appointed **Mr J. H. Ross** as managing director on the retirement of **Mr J. S. Carter.**

Mr R. D. Watson has been elected as chairman of the Manchester and District Branch of the Institute of Welding. **Mr A. C. White** has been appointed to represent the Institute on the Production Engineering and Mechanical Engineering Trades Advisory Committee of the Union of Lancashire and Cheshire Institutes. Both Mr Watson and Mr White work for British Oxygen Gases Ltd.

British Insulated Callender's Cables Ltd have appointed **Mr J. Floweth** to the position of Nottingham branch manager.

T. JOHNSTON

S. Z. de FERRANTI

R. W. ADDIE

J. BELL

Manager of the Australian office of Humphreys & Glasgow Ltd, **Mr A. S. Humphrys** is on a visit to Britain to study the latest developments in the gasification of oil and coal with particular reference to nuclear power plants, chemical process installations and other fields.

The Institution of Metallurgists have elected **Mr W. E. Ballard,** managing director of Metallisation Ltd as president. **Mr J. W. Bennett,** formerly president of Atomic Energy of Canada has become general manager of the Canadian British Aluminium Co.

Dr L. W. Brown has been appointed assistant chief electrical engineer (light current) of Metropolitan-Vickers Electrical Co Ltd. Dr Brown is also chief engineer of the electronics department.

EMI Electronics Ltd have elected **Mr R. W. Addie** to their board as marketing director. Mr Addie will be responsible for commercial sales both at home and abroad.

Dr R. Week has joined the board of John Harper & Co Ltd, ironfounders, of Willenhall, Staffs.

Chairman of the North of Scotland Hydro-Electric Board, **Mr Thomas Johnston** has been appointed president of the British Electrical Development Association in succession to Viscount Chandos. **Lt-Col E. H. E. Woodward** was made a vice-president of the Association.

Mr R. C. Hesketh-Jones, formerly sales director (industrial division) of British Oxygen Gases Ltd has been appointed chief executive (overseas) of The British Oxygen Company. **Mr R. J. Foster** succeeds Mr Hesketh-Jones at British Oxygen Gases.

Vitro Engineering Company of New York have appointed **John T. Bailey** as chief design engineer.

OBITUARY

Mr George Alfred Sydney Harvey, president and son of the founder of G. A. Harvey & Co (London) Ltd died on May 28. Mr Harvey was in his 74th year.

The death occurred on May 16 of **Mr G. C. Cunningham,** OBE, joint managing director and a founder director of Racal Engineering Ltd.

Mr Alfred Goad, London representative of Abingdon King Dick Ltd died suddenly on May 10.

CATALOGUES AND BULLETINS

Large colourful brochure from Engelhard Industries Ltd illustrates the work of their subsidiaries which include Nuclear Corporation of America Inc, and in this country Baker Platinum Division and Hanovia Ltd.
Tick **No 173** on reply card

New protective coating for metal and concrete surfaces has been developed by Wailes Dove Bitumastic Ltd and is the subject of their technical leaflet No. 6.
Tick **No 174** on reply card

Conveyors, cranes and handling equipment manufactured by Paterson Hughes Engineering Co Ltd is dealt with in their new section 1 of their catalogue.
Tick **No 175** on reply card

Wild-Barfield Electric Furnaces Ltd have available an interesting series of literature on vacuum induction furnaces, vacuum arc furnaces, resistance heated vacuum furnace and vacuum analysers.
Tick **No 176** on reply card

Allen Engineering Review for June 1958 contains, among other things an article on the practical application of steam turbo-alternator control gear by A. C. Valentine.
Tick **No 177** on reply card

Van de Graaffs, modular linacs and super-voltage X-ray equipment are described in new catalogue from High Voltage Corporation Ltd.
Tick **No 178** on reply card

Latest number of 'Lead News,' published by the Lead Development Association, contains news of recent progress in the production of homogeneous lead. Previously made by hand it is now planned to mechanize the process, which will considerably reduce prices.
Tick **No 179** on reply card

Folder containing leaflets on different types of valves and controllers made by Pressure Control Ltd is now available.
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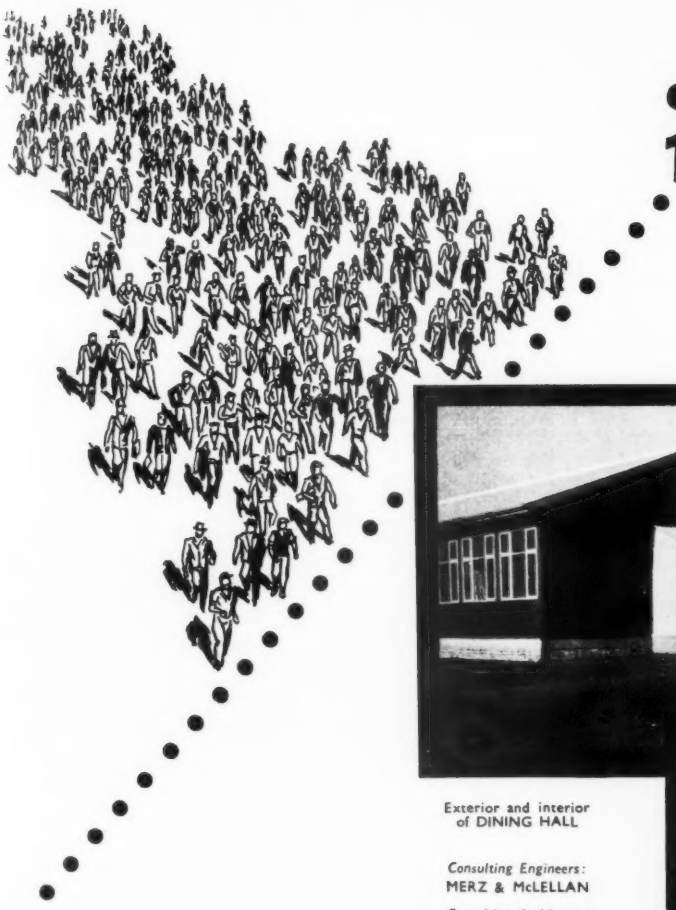

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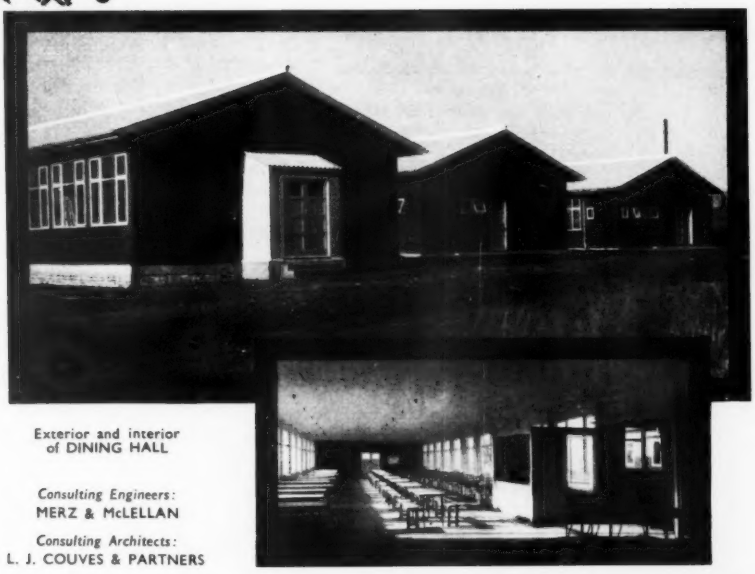

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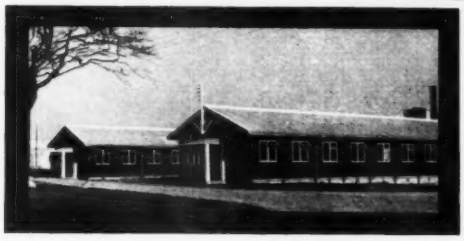

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Reports are also available in the United States, from the USAEC depository libraries, a list of which will be found in NUCLEAR SCIENCE ABSTRACTS. Reports for sale may be purchased in the United States from: Sales Section, British Information Services, 30 Rockefeller Plaza, New York 20, N.Y.

AERE Harwell

The radiography of active uranium cartridges. *J. A. G. Smith, J. Thewlis.* (Sept 1949. 9 pp) AERE G/R 366 2s 6d*

The transient power characteristics of BEPO under an automatic power regulator. *J. H. Bowen.* (April 1950. 21 pp) AERE E/R 510 3s 6d*

A method of determining isotopic composition of uranium samples. *J. Derham.* (Dec 4, 1951. 7 pp) AERE R/R 834 1s 9d*

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Gravimetric determination of uranium in uranyl nitrate solutions (after separation by ether extraction). (March 1958. 6 pp) IGO AM/W-116

On the ductility of polycrystalline beryllium. *J. F. W. Bishop.* (Feb 1958. 12 pp) IGR TN/S-791

Heat transfer in channels composed of rough and smooth surfaces. *W. B. Hall.* (Feb 1958. 12 pp) IGR TN/W-832

United States

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Scintillation spectrometry gamma-ray spectrum catalogue. (July 1957. 180 pp) IDO 16408 $4.75

Concerning the multigroup diffusion operator. (Sept 1957. 19 pp) KAPL 1867 50c

(n, 2n) Study of Be^9. (Oct 1957. 19 pp) LA 2158 75c

Reactor physics quarterly progress report April–June, 1957. (Jan 1958. 8 pp) NAA-SR 2058 50c

Reactor kinetics quarterly progress report October–December 1956. (Jan 1958. 55 pp) NAA-SR 2134 $1.50

Development of a laboratory-size fluidized-bed reactor. (Nov 1957. 40 pp) HW 51834 $1.25

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Irradiation of organic reactor coolants in dynamic systems. (Nov 1957. 42 pp) HW 53717 $1.25

Experience with thulium radiography at the MTR. (Oct 1957. 37 pp) IDO 16333 $1

Three-channel alpha fission counter. (July 1957. 13 pp) KAPL 1827 50c

An autographic strain-gauge dialtometer for plutonium and its alloys. (June 1952. 24 pp) LA 2157 50c

Reactor safety quarterly progress report January–March 1957. (Dec 1957. 20 pp) NAA-SR 2157 50c

Reactor safety quarterly progress report April–June 1957. (Mar 1958. 22 pp) NAA-SR 2224 75c

Portable mercury vapour detector. (Jan 1958. 45 pp) Y 1188 $1.25

Roll cladding uranium-zirconium and uranium-zirconium-niobium alloys with Zircaloy 2 for plate-type fuel elements. (Feb 1958. 228 pp) ANL 5628 $6

Process studies on zirconium and uranium, progress report for period: November 1, 1949 through March 31, 1950. (April 1950. 119 pp) BBC 53 $2.75

Aqueous corrosion of uranium-fuel element cores containing 0 to 20 w/o zirconium (Jan 1957. 33 pp) BMI 1156 $1

Final report on reactor fuel element research, development and production. (May 1950. 58 pp) BNL 54 $1.50

Ultrasonic-detection of surface defects in uranium. (Sept 1957. 30 pp) HW 51979 75c

Preparation of nuclear poison and control alloys, zirconium-boron alloys. (July 1957. 30 pp) KAPL 1555 $1

Phase diagram studies of zirconium with silver, indium and antimony. (Aug 1957. 52 pp) ORNL 2344 $1.50

Nuclear decay scheme analysis and characterization studies of (d.a) reaction products, project No. 7 (May 1957. 232 pp) AECU 3514 $5.50

ERRATA—DATA SHEET No 6 D.C. Amplifiers for nuclear reactors

Integra, Leeds & Northrup Ltd.—*Entry under 'Potentiometric Pen Recorders' should be amended as follows. This correction slip is designed to be pasted over the erroneous entry.*

Electronic Instruments Ltd.—*Input stability should read* $\pm$ 100μV/12hrs.

FIRM	INPUT VOLTAGE OR CURRENT RANGE	BACKING-OFF FACILITIES	SCALE LENGTH	TIME FOR FULL SCALE	ACCURACY	CONTACT FACILITIES	RETRANSMITTING FACILITIES
Integra, Leeds & Northrup Ltd. *Egbaston House, Birmingham 15*	100μV–1000mV Max. source imp. 2000 Ω – 10^9 Ω 3×10^{-9} amp. up	yes	10 in. straight	1 sec.	$\pm$0·3 pc. f.s.d.	Alarm contacts or on-off, or 2 or 3 term electric controller	slide wire or pneumatic

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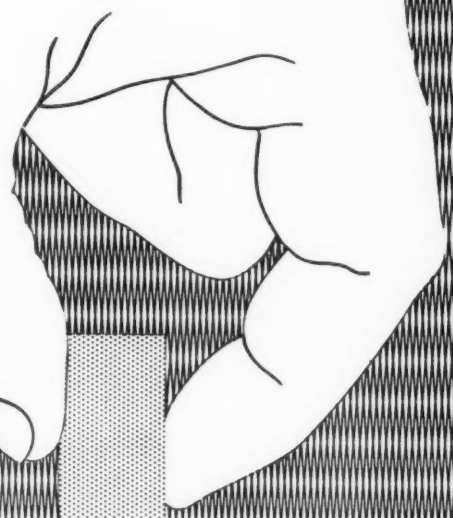
designed to permit rapid fuel charge or discharge under load in absolute safety. Your enquiries for equipment of a similar nature are invited.



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# of oil after radiation

Here was a problem of national importance. Lubricants were needed by the nuclear industry for reactor equipment, much of it subjected to radiation. Yet, like human beings, oils and greases were vulnerable to radiation. Oils darkened in colour and became coarse-grained solids (solidification being but one of a tangled skein of problems).

The Shell Group started working on the problems of lubricating under radiation conditions while most nuclear power stations were still on the drawing board. In fact, Shell was the first oil company to develop Atomic Power Lubricants, and the research that went into Shell A.P.L. is characteristic of the way Shell sets about doing things. A team of research workers was assembled at Shell's Research Centre at Thornton. Series of tests were carried out both in the B.E.P.O. pile at the U.K. Atomic Energy Authority Research Establishment, Harwell, and with Thornton's own Cobalt 60 source of radiation. In 1957, after four years of research, Britain's first range of Atomic Power Lubricants was on the market.

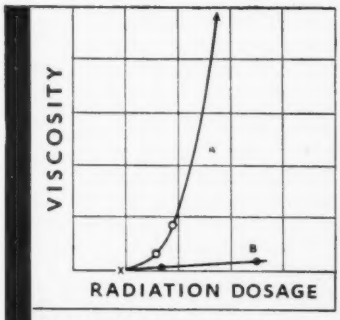
The moral of the A.P.L. story is that Shell research is supremely applicational. The Centre at Thornton is always ready to work with even the most specialised sectors of industry to produce the right oil for the job. If you and your organisation have any major lubrication problems, it will pay you to get in touch with your local distributor of Shell Industrial Lubricants.

The Research Story

In the hundreds of complex hydrocarbons examined, very different reactions to radiation were observed according to the configuration of the atoms in the molecules. When carbon atoms were arranged in long, straight chains, radiation caused these chains to link up with one another, giving highly complex structures of an entirely different nature from the original material. The first effect of this change was to cause a rapid increase in viscosity, ultimately giving rise to a solid rubber-like product.

For example, a high quality turbine oil conforming to BSS.489 receiving a dosage of 1.77×10^{18} neutrons/cm² was changed into an intractable solid—a clear demonstration that radically new lubricants were needed by the nuclear industry.

Shell Atomic Power Lubricants have a molecular structure that has proved itself very resistant to radiation. In fact it will withstand a radiation dosage four million times stronger than that which will kill a man—without any significant change in structure or physical properties.



Relationship between radiation dosage and percentage increase in viscosity, cS at 100°F.
Oil A: high molecular weight long chain hydrocarbon. *Oil B:* Shell A.P.L. 731.

SHELL

ATOMIC POWER LUBRICANTS

another proof of Shell leadership in Lubrication

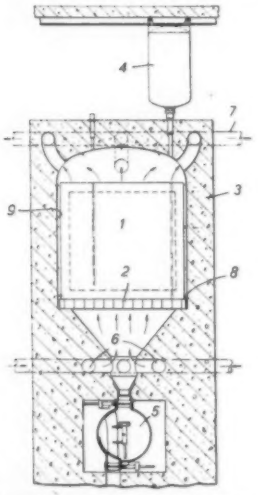
NEW IDEAS

nucleonic patents

Concrete pressure vessel

By building the pressure vessel of a gas-cooled reactor of thick concrete, GEC suggest that it could also form the whole or part of the biological shield. A thin metallic lining—suitably steel—is incorporated to prevent gas diffusion into the concrete and also to act as shuttering while the concrete is being cast. It is formed of a series of flanged plates initially bolted or clamped together during casting and finally seal welded along the outer edges.

The idea is worked out for a cylindrical vessel but it is equally applicable to a spherical one and the inventor says it could be adapted as the pressure vessel



795,826 SHIELD-CUM-PRESSURE VESSEL

1	Core	6	Gas inlet
2	Grid	7	Gas outlet
3	Concrete pressure vessel	8	Gas seal
4	Charge machine	9	Metallic lining
5	Discharge machine		

for Hunterston (patent 785,945, NUCLEAR POWER, February, 1958). The outer shell would then be of metal-lined concrete.

795,826 Improvements in or relating to nuclear reactors *The General Electric Co Ltd* (inventor: D. W. T. Angwin) Appn: Aug 11, 1955 Pubd: May 28, 1958.

Improved tubular element

One of the disadvantages of tubular fuel elements is that unequal dimensional changes occur due to temperature changes and irradiation effects. One sheath is brought into tighter contact with the fuel while the other makes poorer contact so that there is an unequal distribution of heat to the two cooling surfaces. This patent aims to overcome this with an element comprising a tube of beryllium with longitudinal bores containing uranium rods. The tube may be fluted on the inner and outer surfaces to equalize the thickness of metal between them. The fuel may be enclosed by a beryllium plug at each end, argon-arc welded into place. Alternatively, there may be an annular groove at the end of the tube and the seal formed by a beryllium ring welded to the groove wall.

794,901 Improvements in or relating to tubular fuel elements for nuclear reactors *United Kingdom Atomic Energy Authority* (inventors: Henry Lloyd and Alan Blainey) Appn: Dec 17, 1951 Pubd: May 14, 1958

No fuel cans

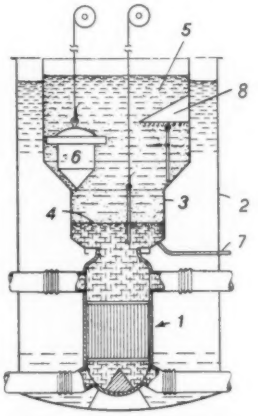
Instead of preventing the circulation of gaseous fission products in a gas-cooled reactor by canning the fuel elements, this is an idea for a reactor in which the poisons, notably xenon, are removed from the coolant chemically. Unsheathed fuel rods are inserted into vertical channels in the graphite moderator and pressurized carbon dioxide passed upwards over them in the usual way. The horizontal boiler has hemispherical ends and is divided by a partition so that the coolant flows in a U-shaped path. Part of the coolant is led off to a water-filled pressure vessel where the carbon-dioxide dissolves and the insoluble xenon with some CO_2 is blown off. The water is then passed through a throttling valve into another vessel with lower internal pressure and degasification takes place. Liberated CO_2 is returned by a compressor to the closed circuit passing through a freezer to remove water vapour. The inventors claim that only part of the coolant need be purified as a certain enrichment in xenon is permissible.

794,329 Improvements in nuclear reactors and an improved method of operating nuclear reactors *Babcock & Wilcox Ltd* Appn: June 27, 1956 (in Germany) Pubd: April 30, 1958.

Achieving maximum burn-up

The main design feature of this fast breeder, burning highly enriched U-238 and heavy water cooled, is that the fertile fuel assemblies are interchangeable so that the maximum burn-up is achieved. Both fissionable and fertile fuel elements comprise a number of thin plates put together to form an assembly about six inches square and six feet long. Core and blanket are arranged in a right circular cylinder and fertile fuel is also dispersed regularly throughout the core. These central elements burn-up more quickly than the blanket and when refuelling takes place they are removed and assemblies from the blanket moved in to take their place.

The refuelling operation is performed as follows: the shielding tank 3 is filled with heavy water to the level 4 and then with a clear organic liquid such as diphenyl and liquid silicones which are immiscible with water. The charge/discharge machine is moved over, removes the closing plug 6 and then the fuel elements, hanging those to be transferred



739,916 AMERICAN FAST BREEDER

1	Reactor	5	Organic fluid
2	Containment tank	6	Closing plug
3	Shielding tank	7	Drain line
4	Heavy water level	8	Fuel rack

to the core centre on the rack 8. The heavy water level is sufficiently high to allow the elements to be moved without exposing them to the shielding fluid.

739,916 Breeder-converter nuclear reactor and method of manufacturing fissile material in the same *Babcock & Wilcox Co (USA)* Appn: Sept 27, 1955 (in America) Pubd: April 23, 1958.

Keeping the elements in

In a gas-cooled reactor with horizontal channels, the coolant pressure may be sufficient to expel the fuel elements. This AEA design is for a retaining device for coupled strings of elements, probably in BEPO. The aluminium fuel cans are attached by circumferential wires to graphite carriers sliding in a groove in the channels. These carriers have a coupling hook at each end, mating with the adjacent one as each is pushed into the channel. The retaining device also has a hook which engages with the end element and it engages the reactor face by two cranks on pivots, locked in position by a gravity and spring biased rod. For discharging, pressure on the rod releases the retainer and the whole coupled string can be withdrawn.

794,981 Improvements in or relating to retaining devices for fuel elements in gas-cooled nuclear reactors *United Kingdom Atomic Energy Authority* Appn: May 6, 1954 Pubd: May 14, 1958

These abstracts are made from British Patent Specifications with the permission of the Controller of Her Majesty's Stationery Office. Complete specifications can be obtained from the Patent Office (Sales Branch), 25 Southampton Street, London, W.C.2. 3/6 a copy (including postage, inland and abroad)

RITCHIE CALDER'S *Signposts to the Atomic Age...*

A Harvest for the Desert

"IN A CAVE ON MOUNT CARMEL, in the Holy Land, Dr. Dorothy Garrod unearthed flint sickles, set in carved bone handles—proof that eight thousand years ago, men harvested grain. On Mount Hermon, to the north, Aaronsohn found the coarse grasses—wild wheat and barley—which these early men had recognised as food.

All those thousands of years ago, long before Abraham and the Patriarchs, these ancestral men realised the virtues of grain. They nibbled the seeds in the ears. They discovered that from those seeds more grasses and more seeds grew; that if they scratched the ground the seeds grew better, and, then, if they chose well-watered soil, as in the river valleys, the grains were more plentiful.

That, not the domestication of animals for pastoral herding, was the beginning of civilisation. When men tilled the ground, they became settlers. Their primitive homesteads grew into villages, villages into towns, and towns into cities. Agriculture led to culture.

Grain husbandry spread up the Danube into Central and Western Europe. Rye and oats began their careers as the weeds in the Levantine wheat and barley fields. By climatic selection, they prevailed as the hardy crops of Northern Europe.

Bread-grains and rice are the world's staple food. With the world's multiplying population, we shall have to double the yield in the next twenty-five years. There are two ways of doing that—by getting bigger crops from existing acreages or by increasing the acreages. The first means better seeds and the second means overcoming the limiting factors of climate.

Plant breeders have known since the beginning of the century how that could be done. The science of genetics has taught how, by patient selection and breeding for the characteristics required, crops can be produced for what would seem impossible conditions. The wheats of the Prairie Provinces of Canada abound in what, sixty years ago, was regarded as a belt too arid for cereals. The climate has not changed. The cereals have been man-adapted.

Now, with the help of atomic energy, the crop map of the world can be revolutionised. Crops can be "tailor-made" to grow in the Arctic or in the hot deserts and in inhospitable soils.

By putting seeds in atomic reactors, or placing a radioactive source (such as Cobalt 60) in the centre of a field and planting crops in concentric circles round it, plant-breeders can produce in two to five years, the desired qualities which, by normal plant-breeding, might take 25 or even 50 years. The secret lies in the effect of the nuclear rays on what are called 'chromosomes', which are packages of 'genes', or hereditary traits. The packages can be broken up and reassembled by radiation. The changes are random but one in five hundred, will provide the plant-breeder with a particular quality for which he is seeking.

Natural radiations probably produced the changes from grass to grain, which Ancestral Man found foodworthy. Now, with atomic energy, we can decide the types of crops we want and where we want them". [R.C.]

* * *

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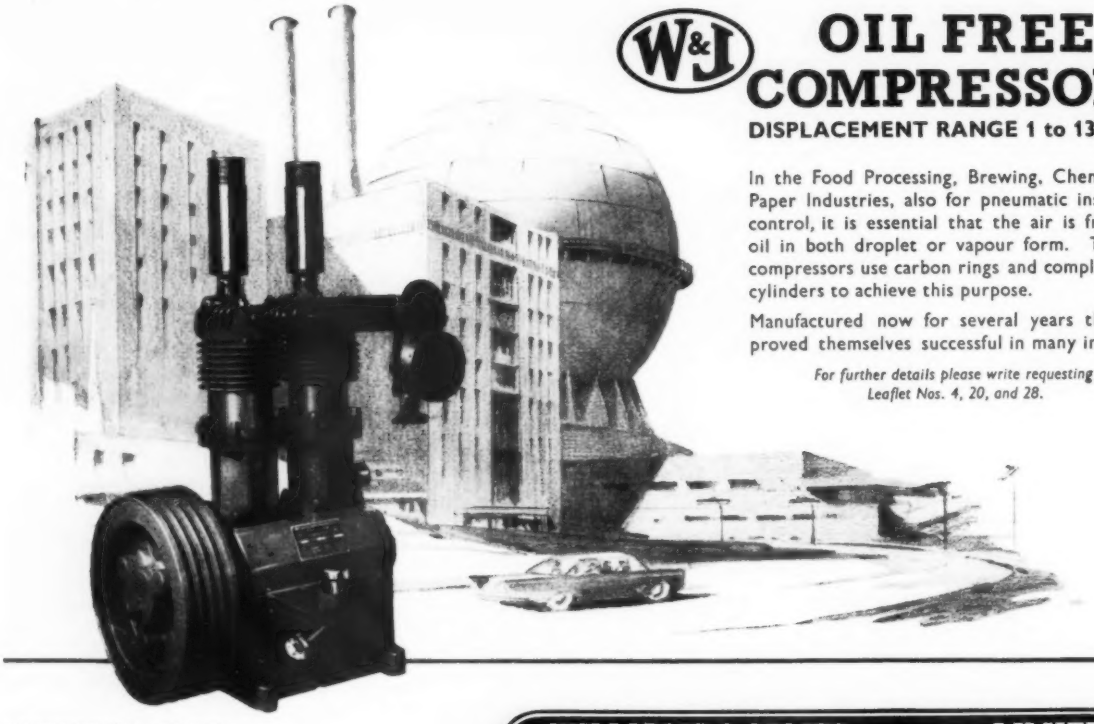

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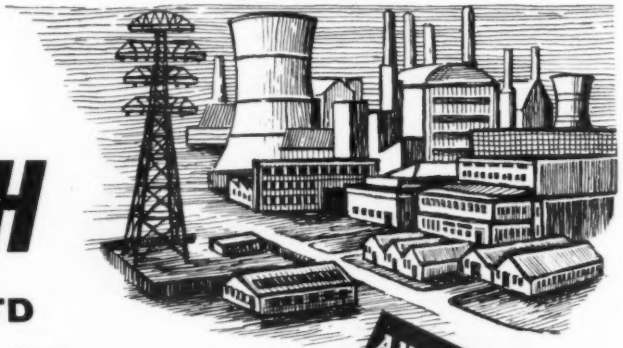

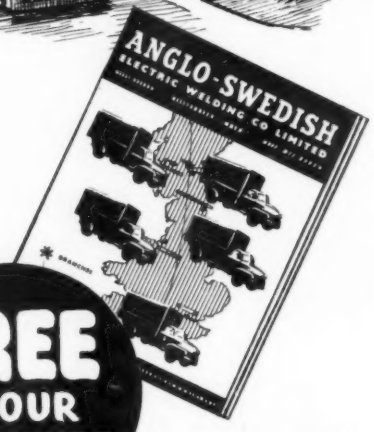

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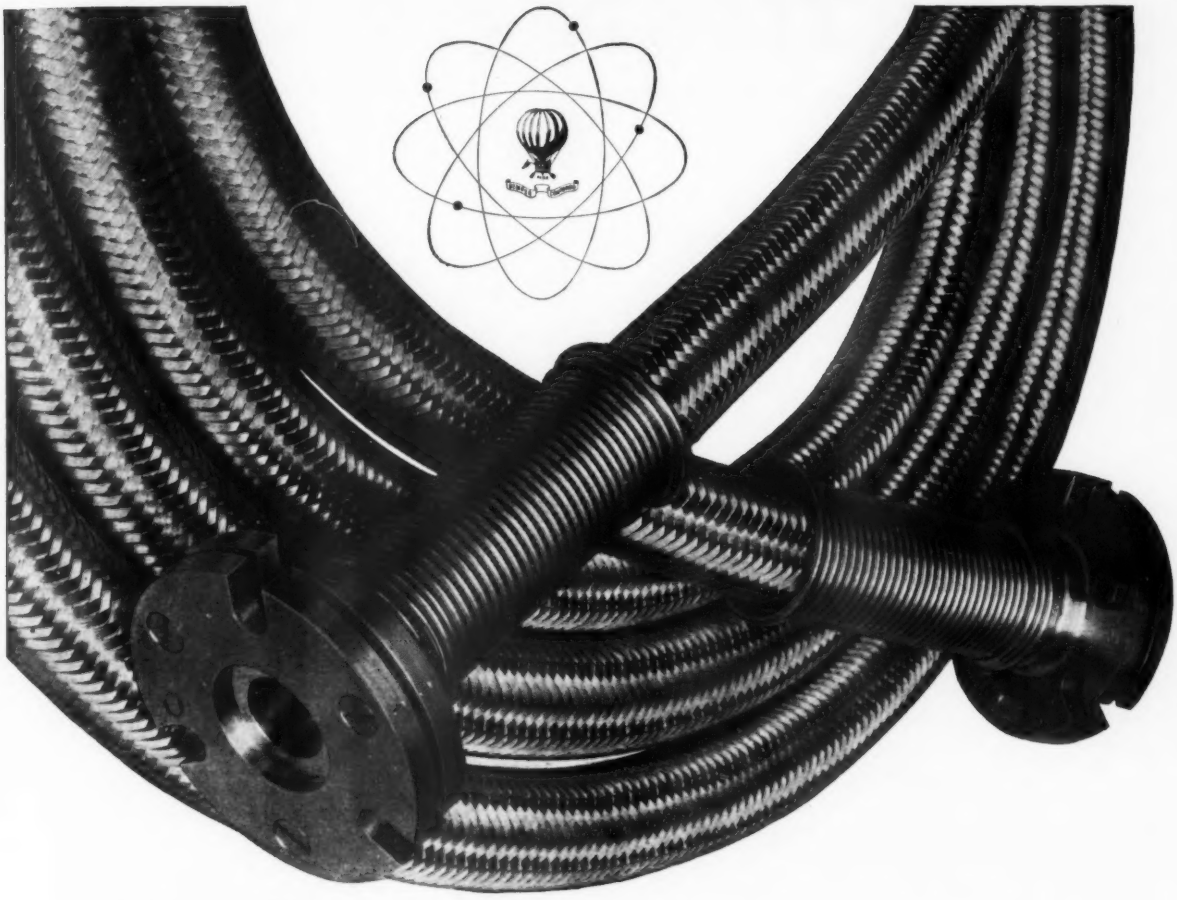

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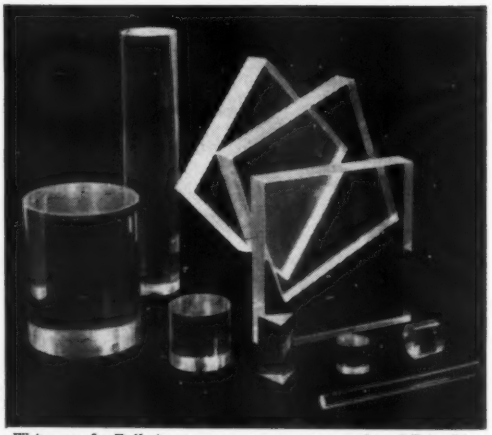

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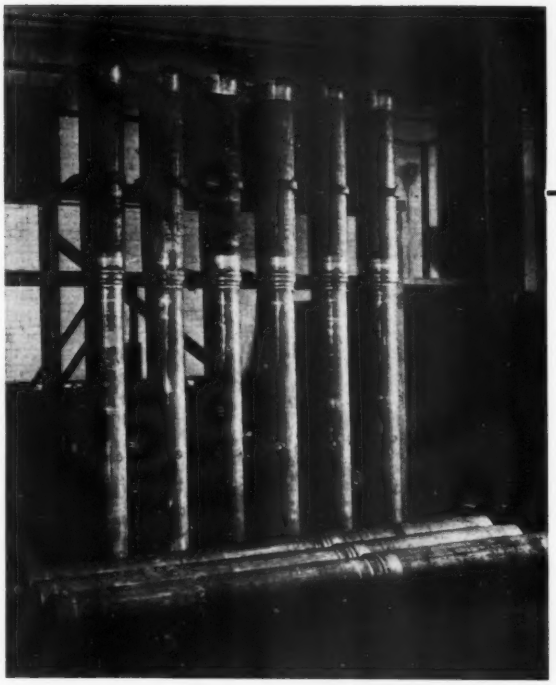

Thermo-couple shield plugs, for Nuclear reactors, being made at Cravens Ltd., Sheffield.

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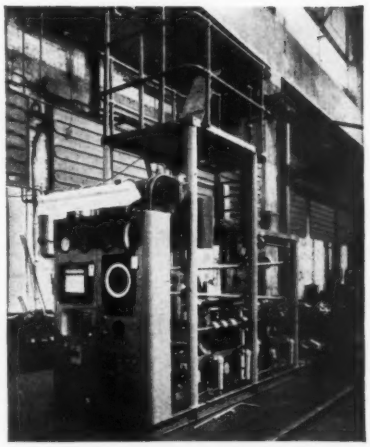

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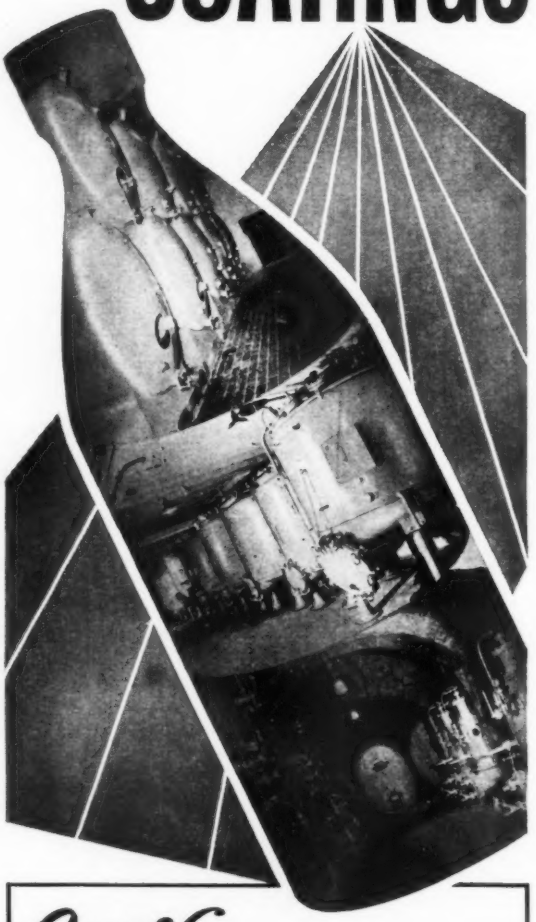

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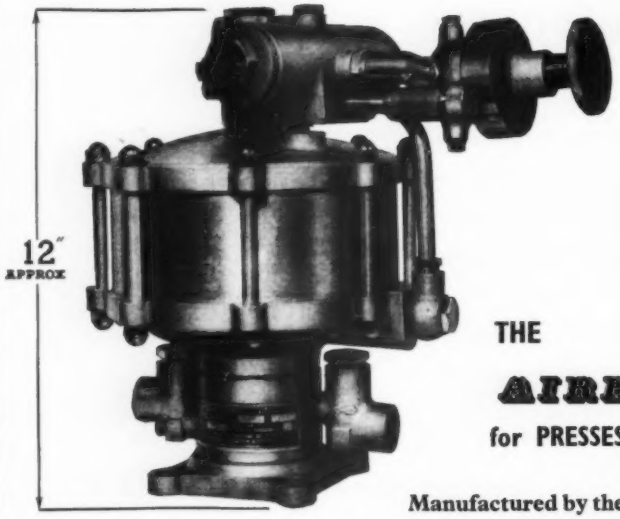

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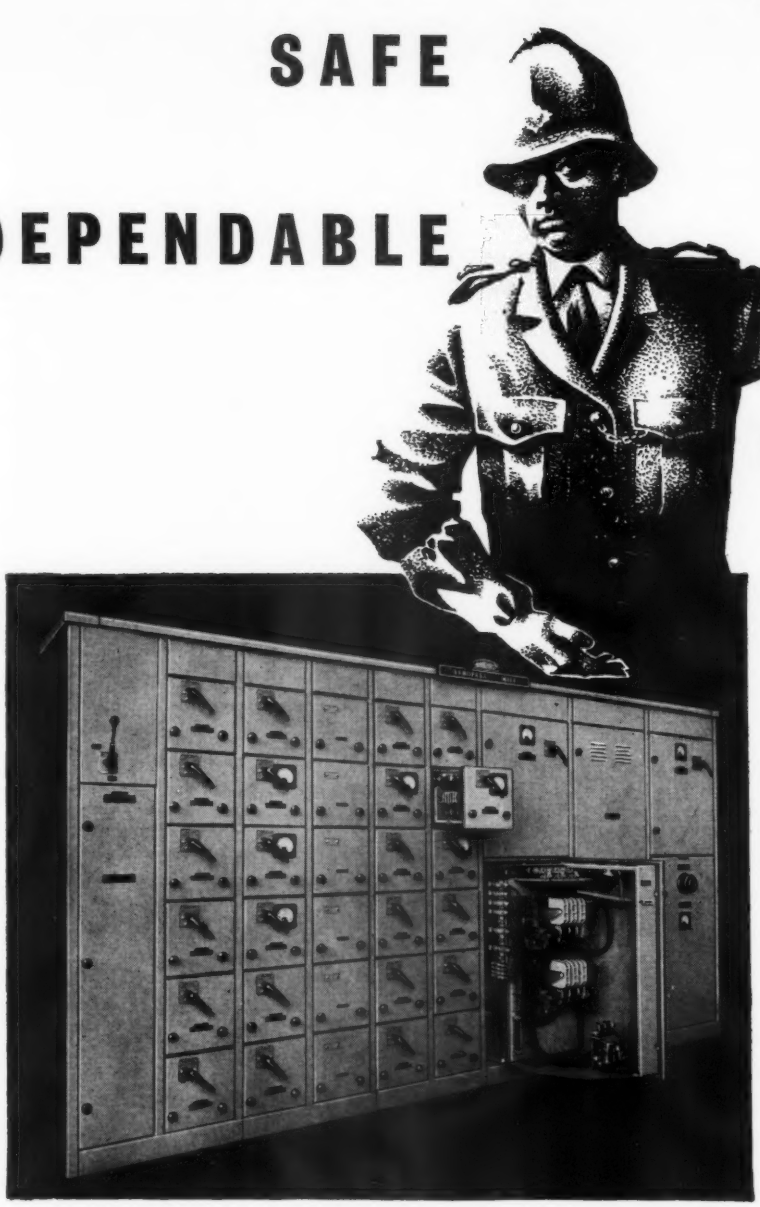

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CHESTER MAJOR SWITCHBOARD

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for S-M-O-O-T-H
Voltage Control

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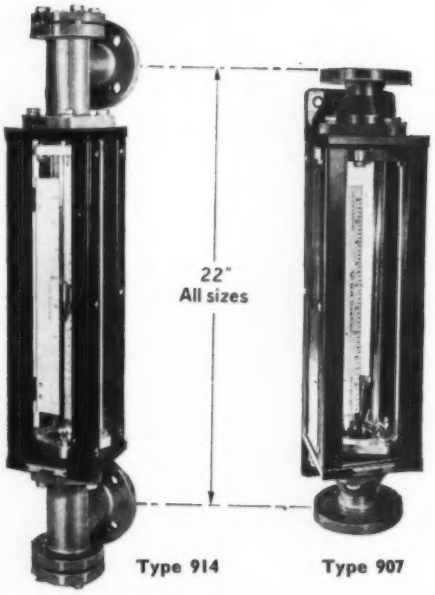

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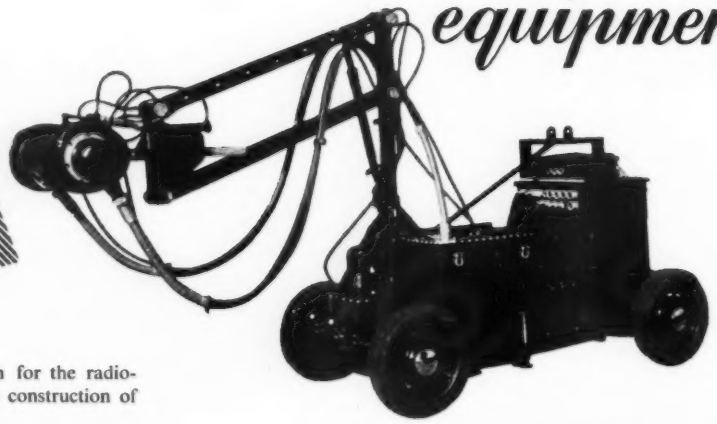

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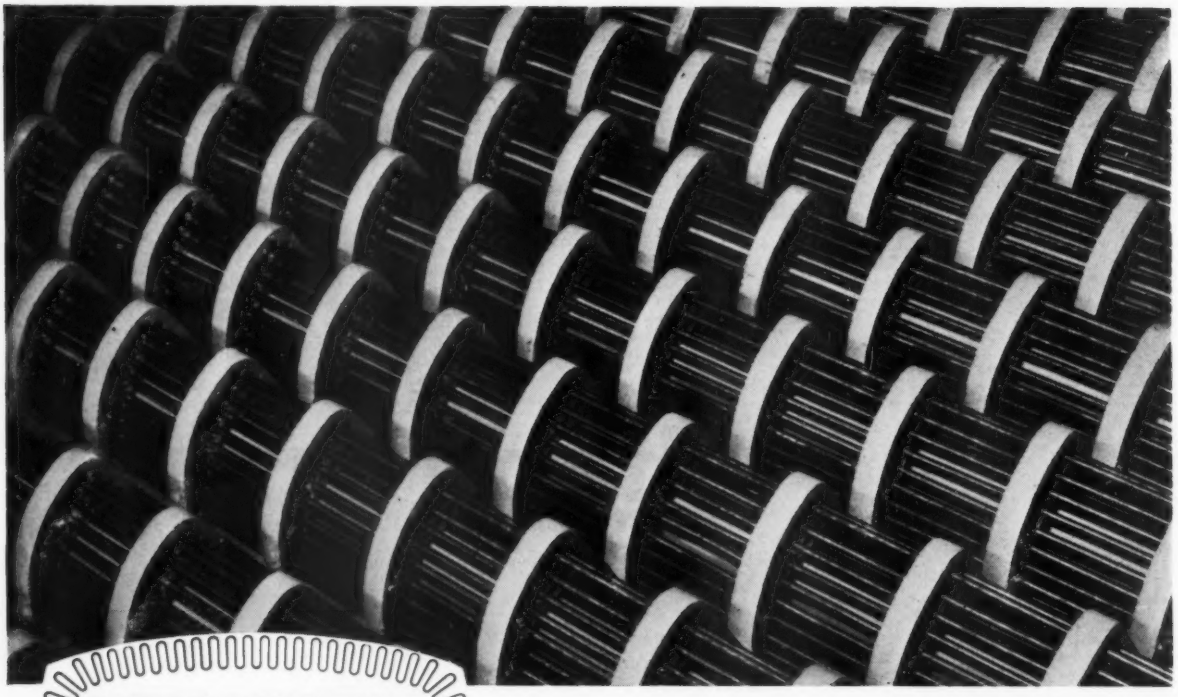

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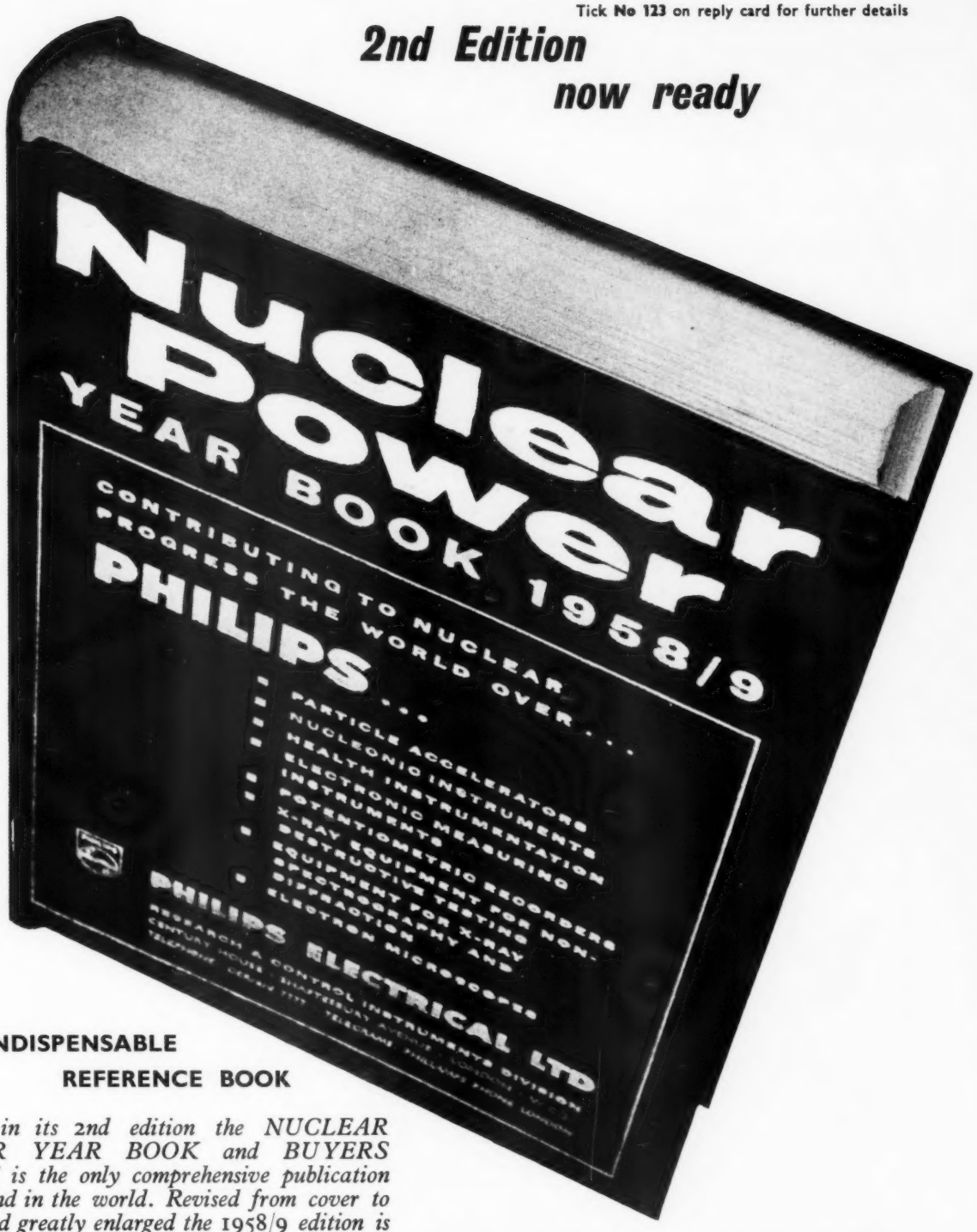

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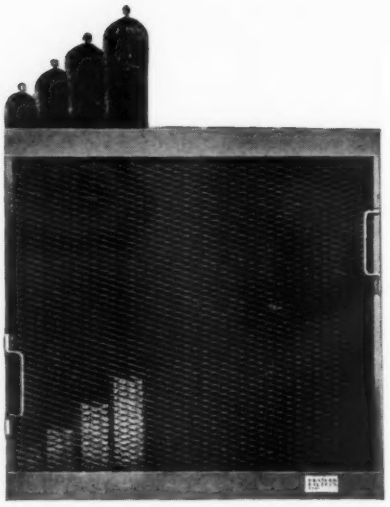

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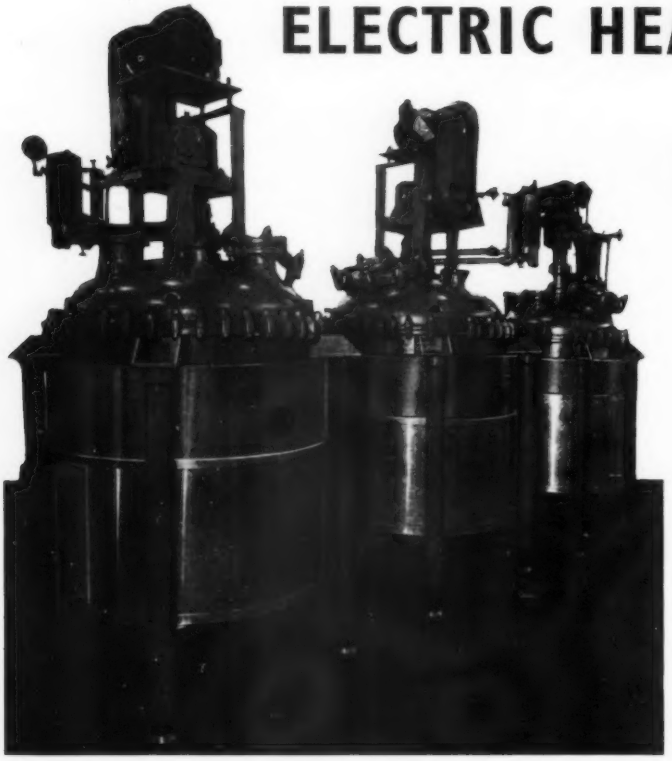

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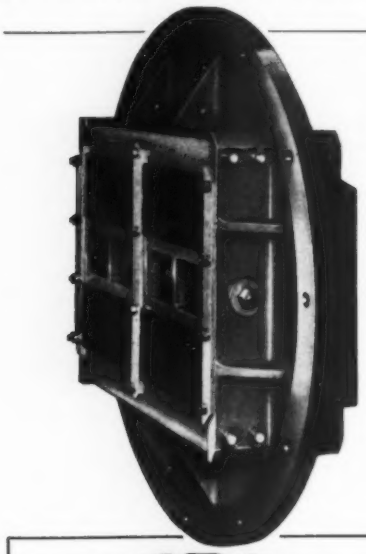

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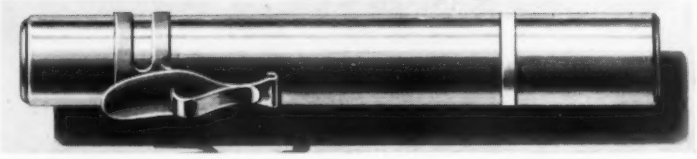

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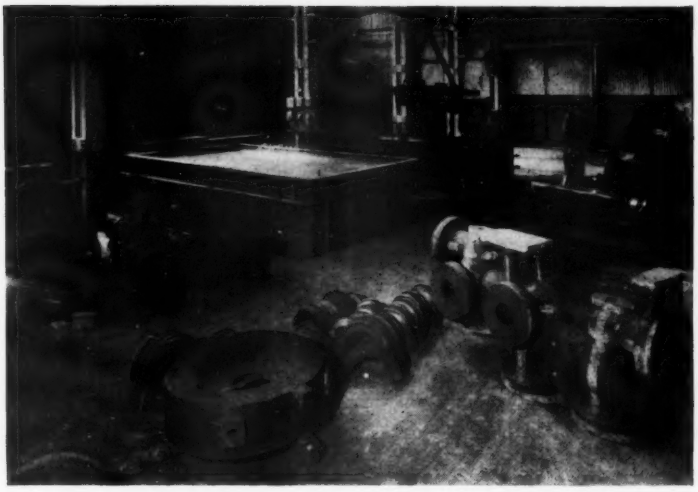
STEEL CASTINGS

For Internal Pressure Work



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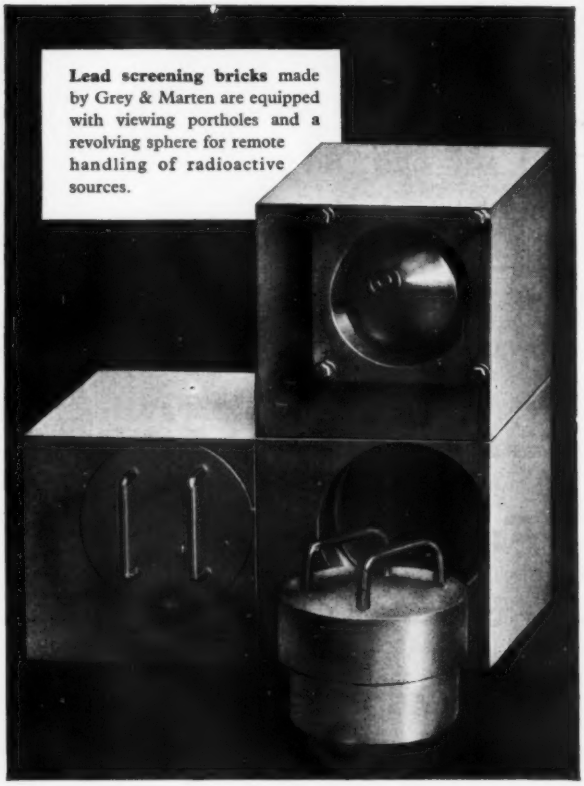

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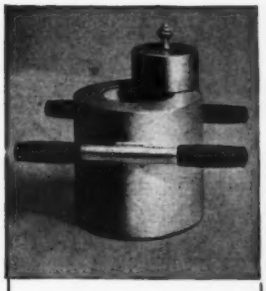

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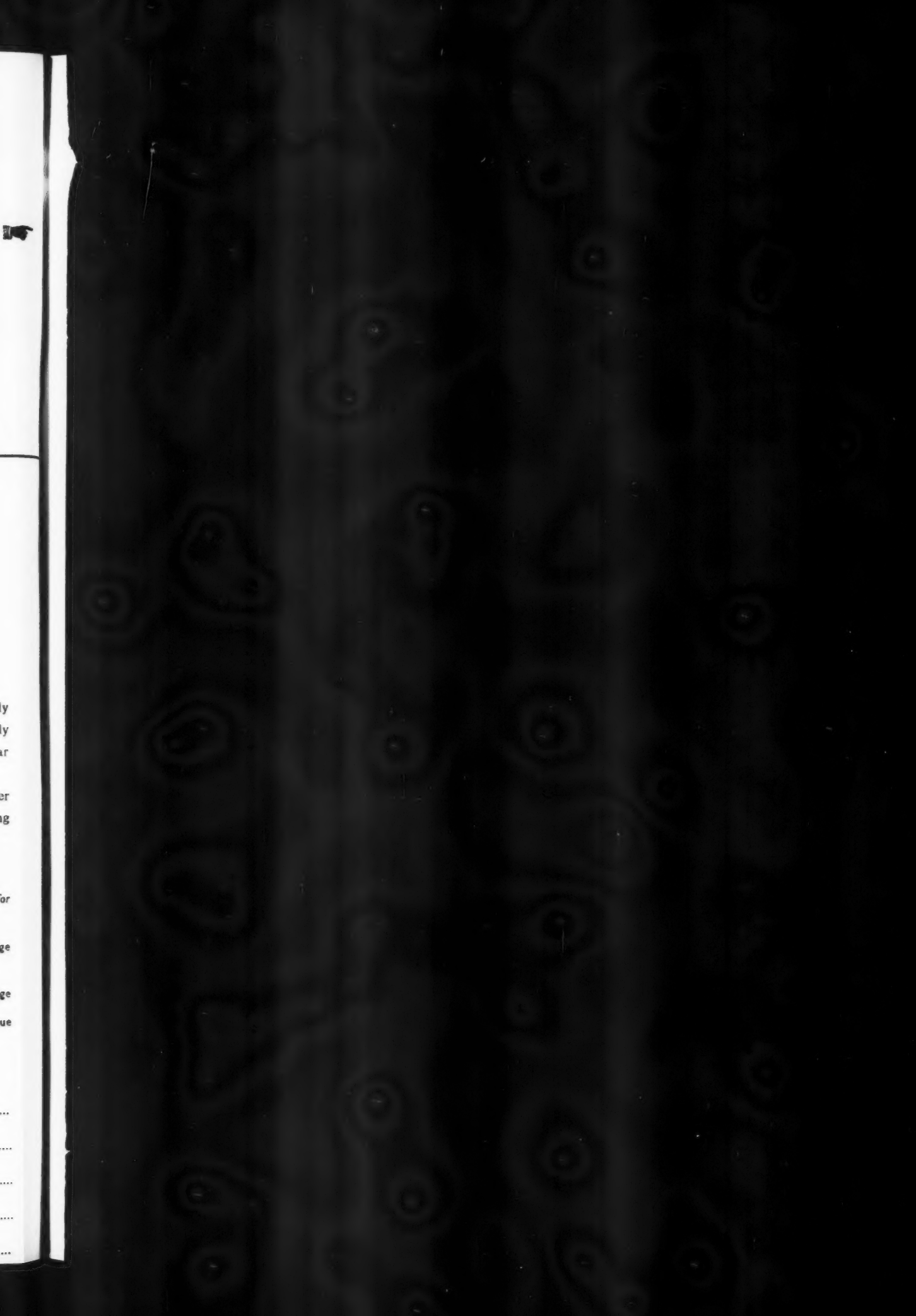

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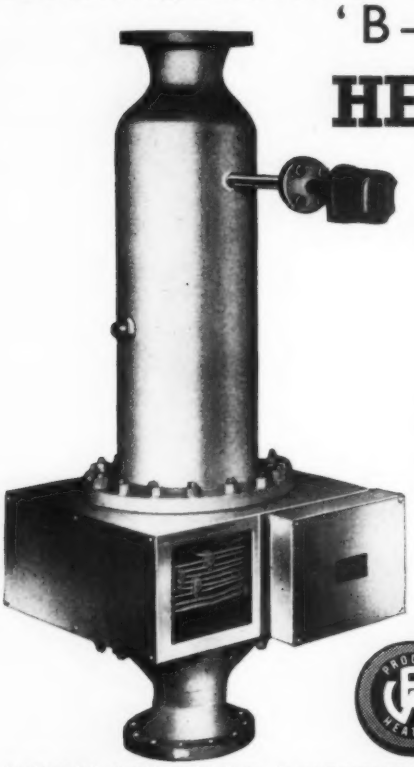

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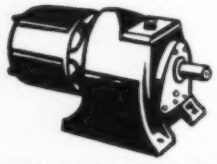

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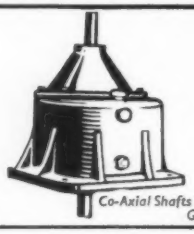

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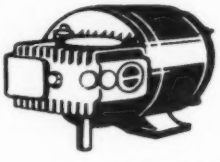

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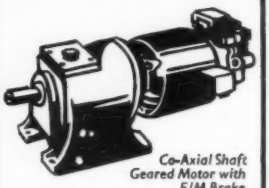

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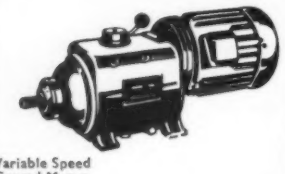

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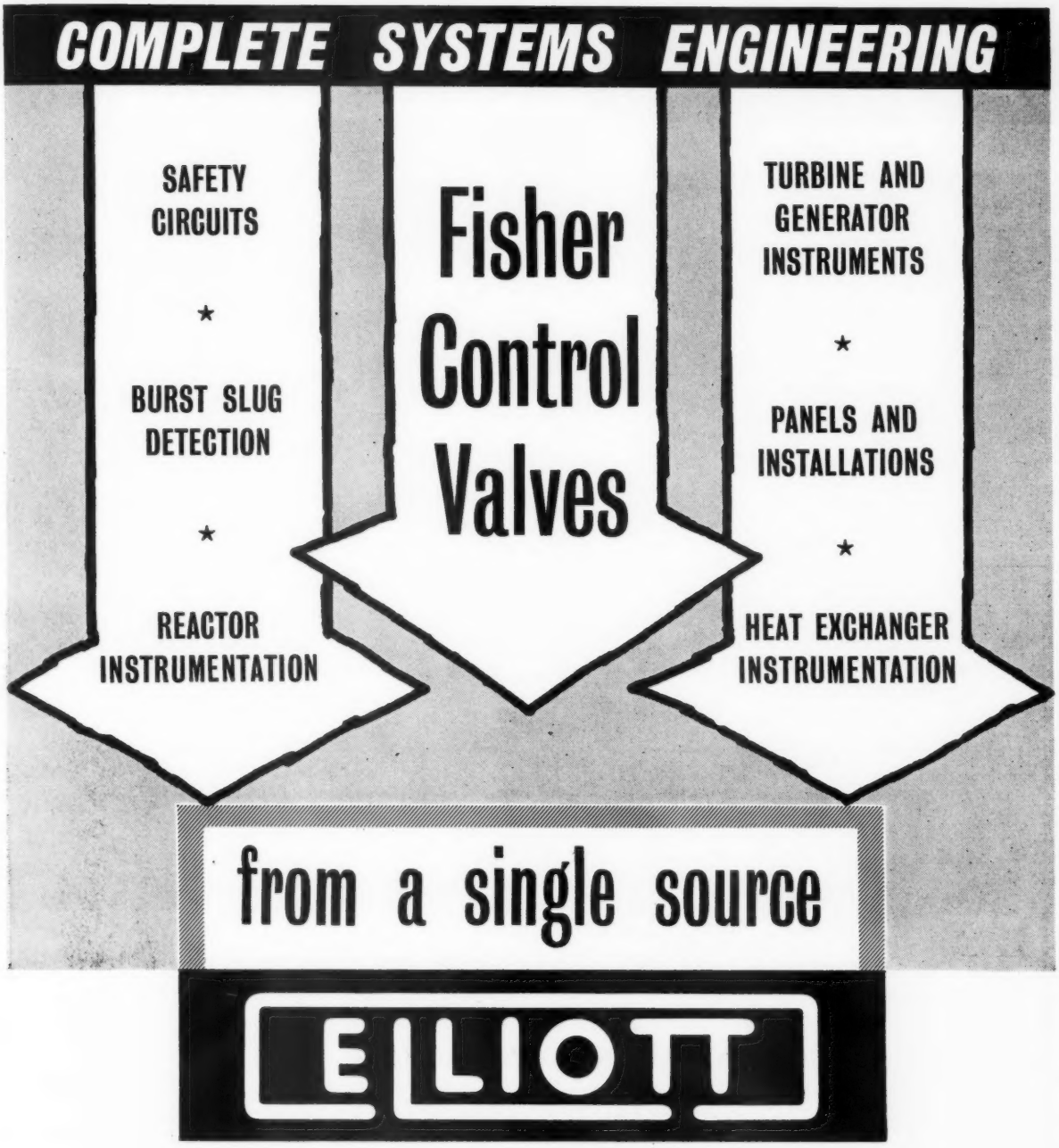

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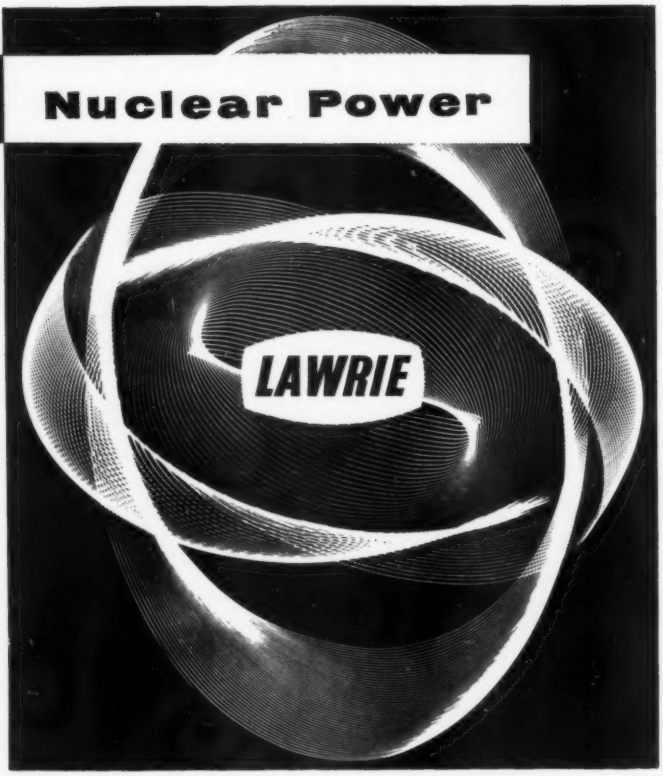

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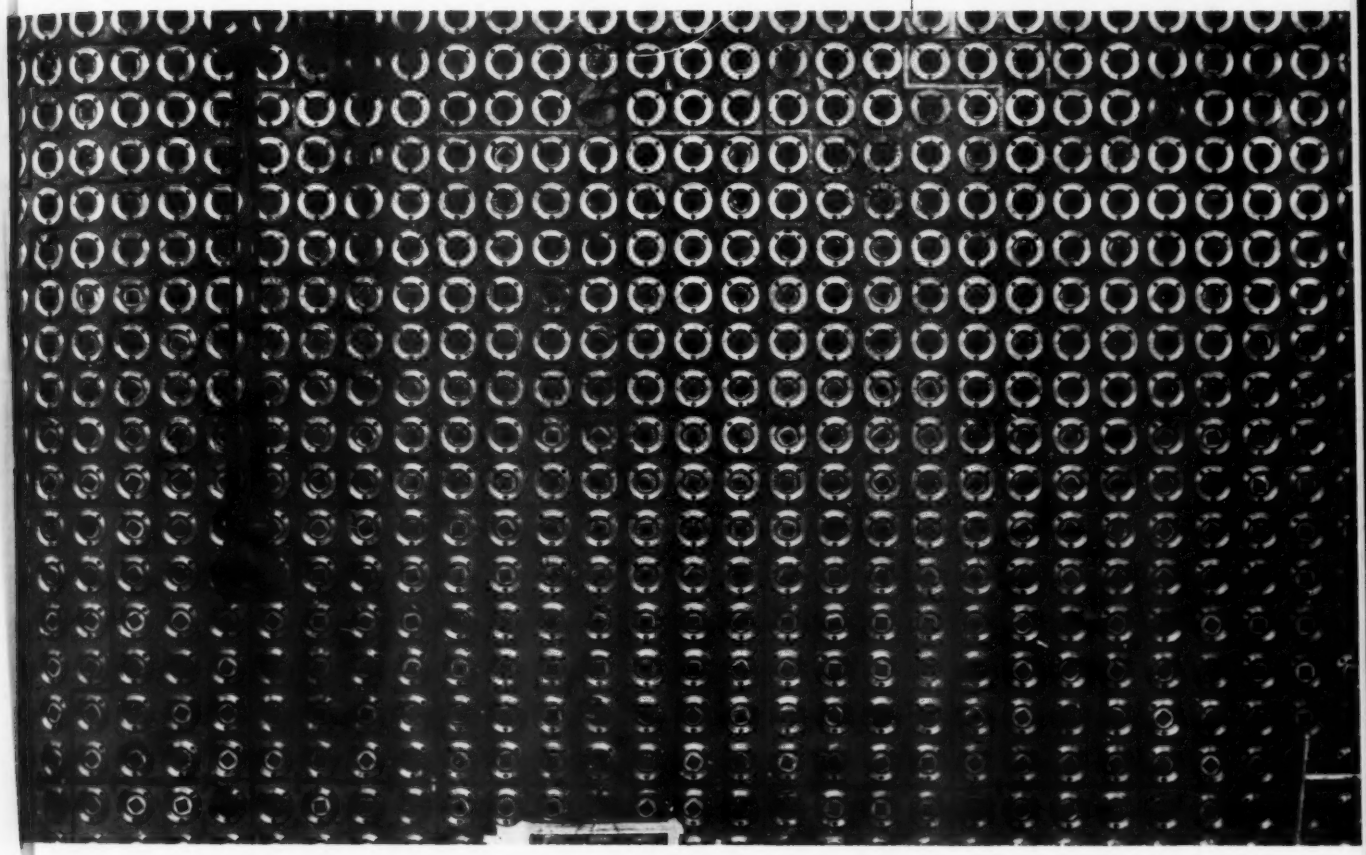

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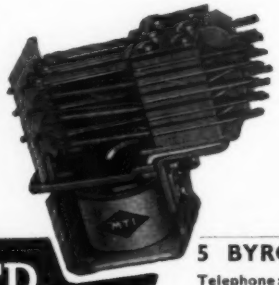

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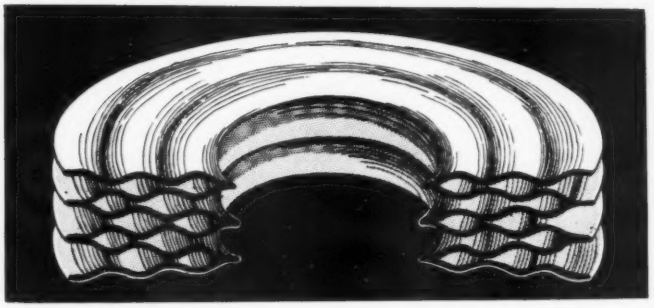

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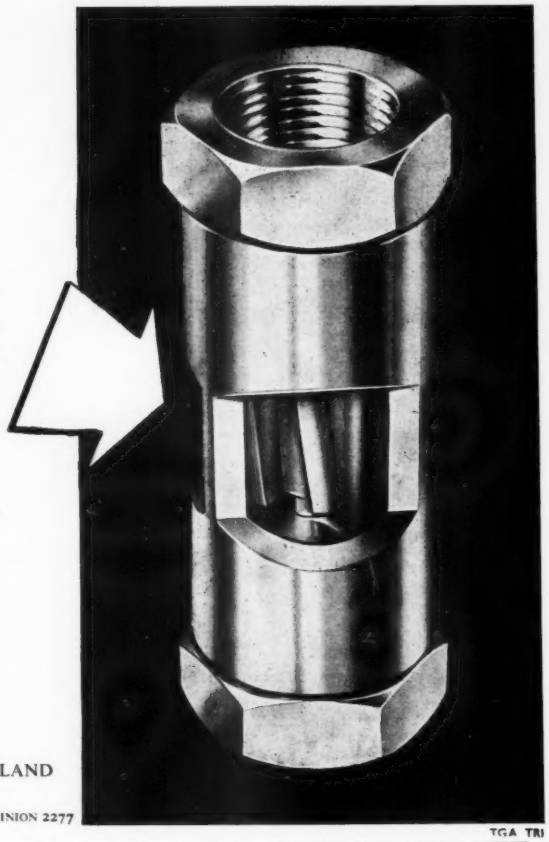

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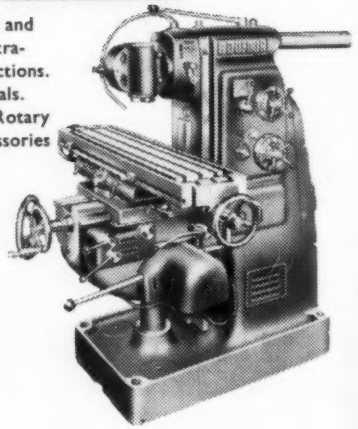

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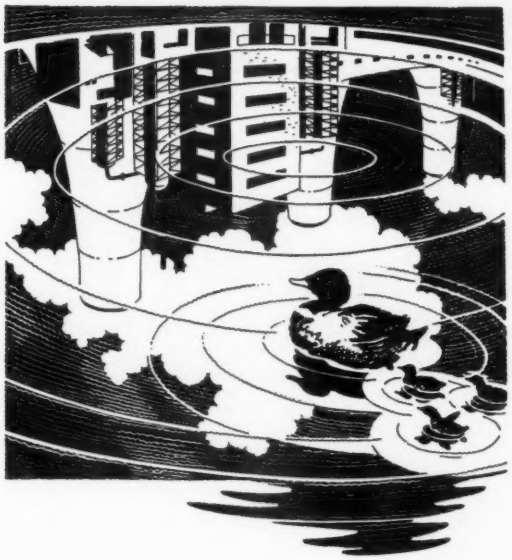

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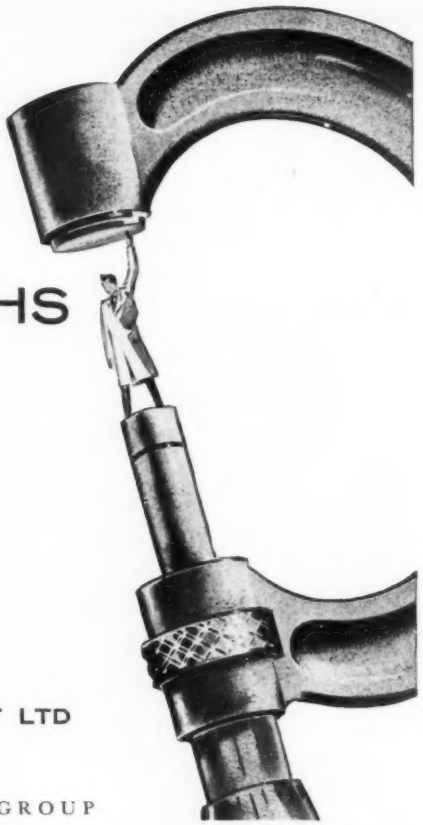

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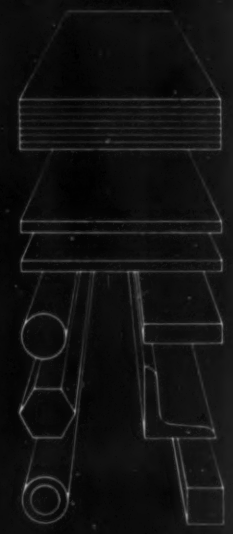

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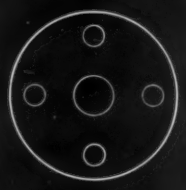

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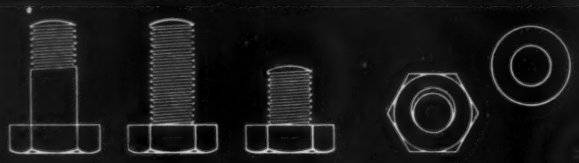

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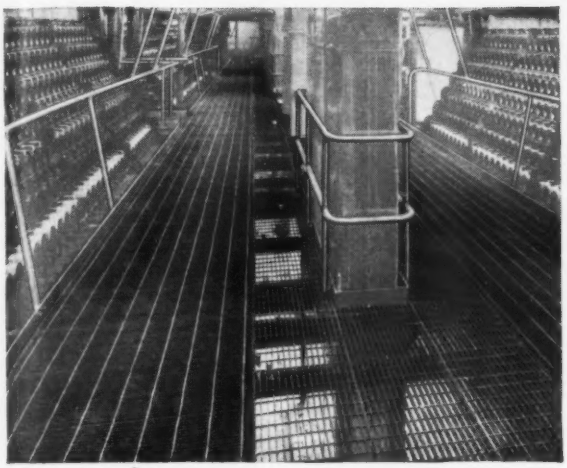

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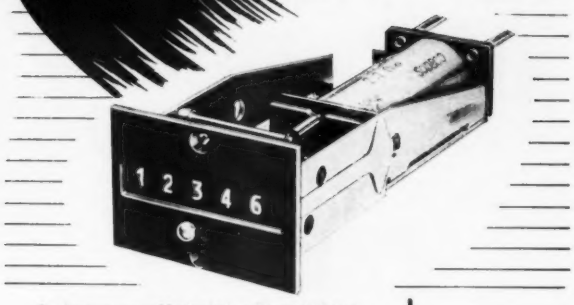

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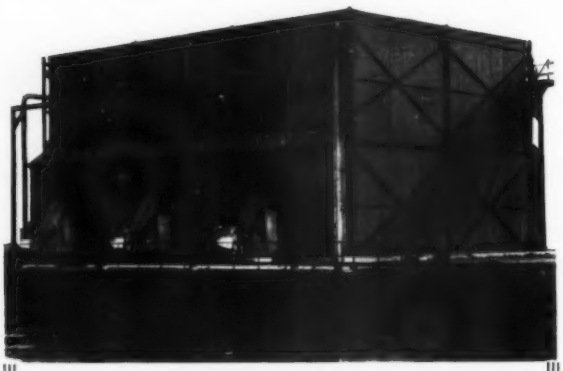

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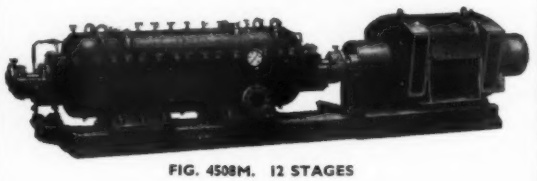

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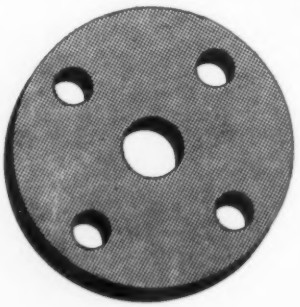

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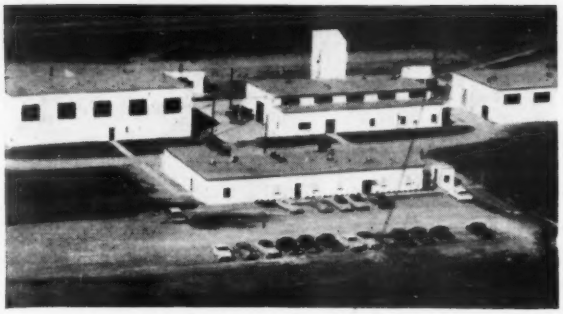

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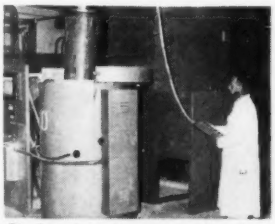
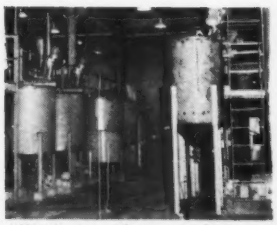


Reduction furnace showing charge of thorium being removed in bomb-type retort.



"Wet" area where uranium and thorium materials are processed in liquid media.

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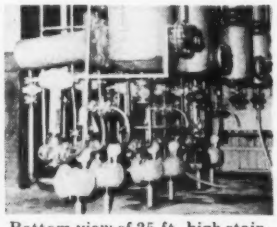

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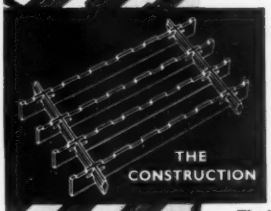

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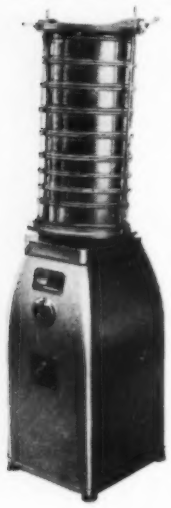

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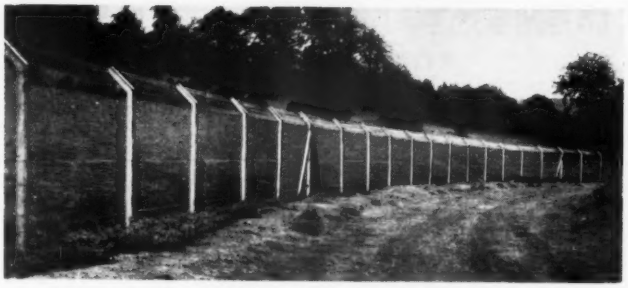

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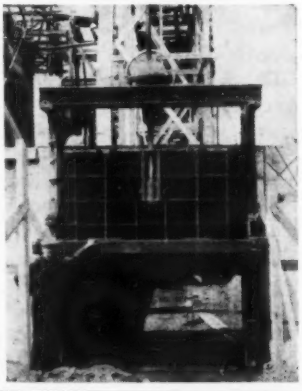

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Applications are invited for the following superannuable appointments at the Board's Nuclear Generating Station which is being constructed at Hunterston, near Largs, Ayrshire :

1. Reactor Physicist. (Reference No. E15/58)

Candidates must have a degree in physics or engineering and must have had some years of industrial experience in a responsible position.

The successful candidate will be responsible for nuclear physics measurements on the reactors and for maintaining technical efficiency of reactor operation. Adequate training will be given in the operation of nuclear reactors.

Salary Range—£1,560 × £35—£1,665 per annum.

2. Health Physicist and Safety Officer. (Reference No. E16/58)

Candidates must have good scientific qualifications preferably of degree standard in either engineering or physics. Some experience in the control of labour will be an advantage.

The successful candidate will be responsible for radiation measurements and for the control of radiological hazards in and around the station. A course of specialized training will be given in health physicist work.

Salary Range—£1,560 × £35—£1,665 per annum.

3. Instrument Engineer. (Reference No. E17/58)

The minimum technical standard will be the possession of a Higher National Certificate. Previous experience of power station instrumentation and control equipment is desirable.

The successful candidate will be responsible for instrumentation and control equipment on both conventional and nuclear plant in the station. A course of specialized training will be given in nuclear instrumentation and control equipment.

Salary Range—£1,325 × £30—£1,415 per annum.

Apply, quoting appropriate Reference No. on standard form AE.6, available from the Secretary, P.O. Box 173, 351 Sauchiehall Street, Glasgow C.2, not later than FRIDAY 18th JULY, 1958.

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Applications are invited for a number of posts in the development laboratory of this Company. Successful candidates would work as members of a team engaged in the application of the techniques of nuclear physics to a wide range of problems. A degree in physics is necessary and one or two years experience of research or development work in similar fields would be an advantage. The company offers attractive salaries and working conditions and the positions will provide ample scope for advancement in this rapidly expanding industry. Applications to The Personnel Manager, **Plessey Nucleonics Ltd,** Weedon Road, Northampton.

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After an initial period of training successful candidates will be based at Hinkley Point Power Station now under construction.

Candidates should have a Higher National Certificate or Degree, or have other suitable technical qualifications in Physics, Applied Physics, Chemistry or Electronics, preferably with some practical experience.

INSTRUMENTATION AND CONTROL SECTION AT BANKSIDE HOUSE, LONDON, SE1 —REFERENCE No 172

Candidates should have a Higher National Certificate or Degree, or have other suitable technical qualifications, in Physics, Electronics or Light Electrical Engineering, with practical experience preferably in Works or Laboratory. Successful applicants will be given any specialized training necessary.

REACTOR DESIGN SECTION AT BANKSIDE HOUSE, LONDON, SE1—REFERENCE No 173

The duties will be to work on problems of radiation levels in relation to Health Physics.

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Salaries for the appointments will be within Scales £1,055-£1,265 and £820-£995 plus London Allowance where appropriate. Application forms obtainable from S. S. Scott, Chief Personnel Officer, 24/30 Holborn, London, EC1, should be completed and returned in envelopes marked "Confidential" by 21st July. Please quote relevant vacancy number.

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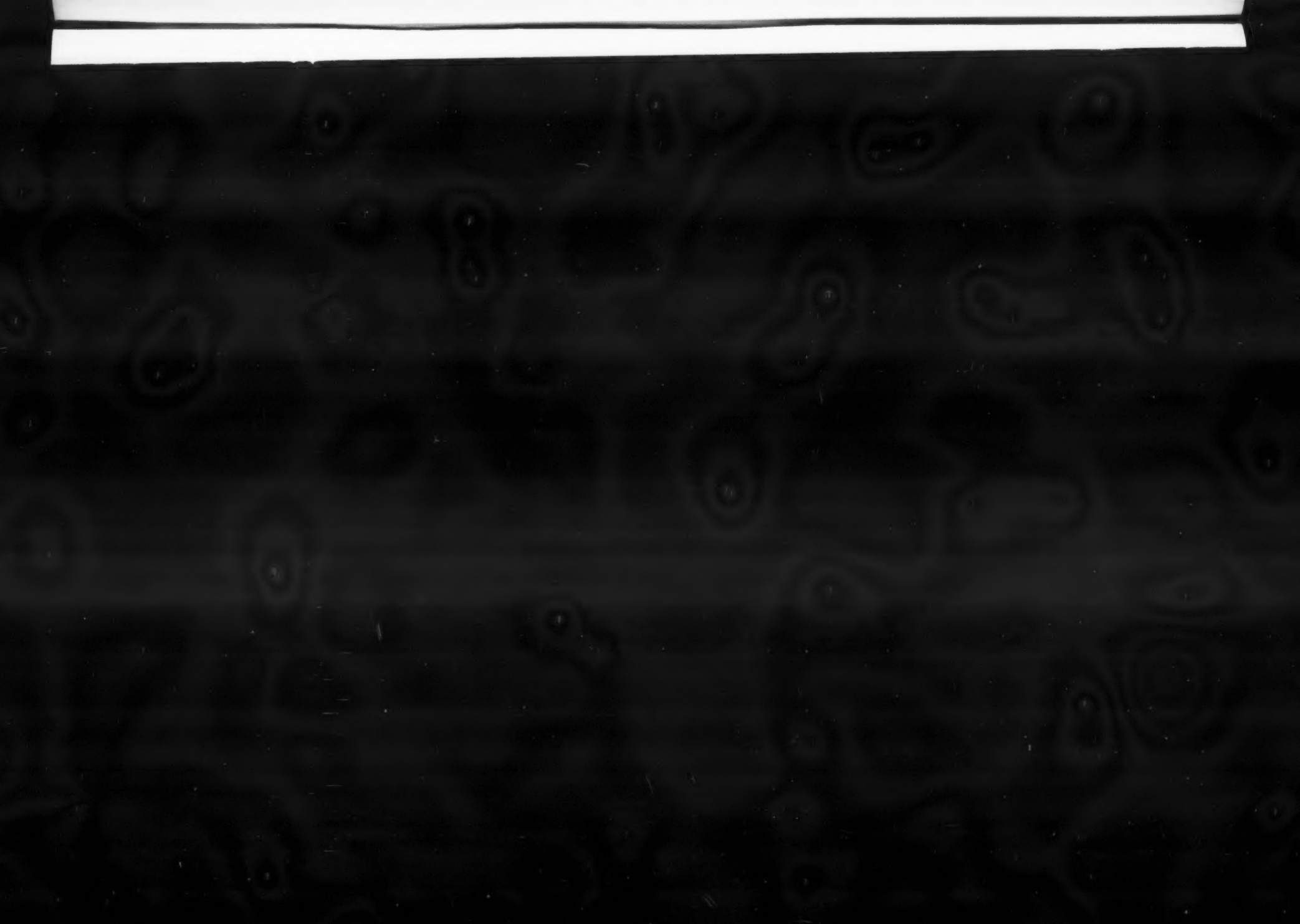

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